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WATER QUALITY STUDIES ON THE COLUMBIA RIVER

Gordon G. Robeck, et al

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

1954

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WATER QUALITY STUDIES ON THE COLUMBIA RIVER

by

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U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Public Health Service
Bureau of State Services
Division of Sanitary Engineering Services
Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

1954

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CHAPTER I

SUMMARY OF FINDINGS AND RECOMMENDATIONS

This study of the Columbia River and its tributaries extended over a period of about two years, from the spring of 1951 to the spring of 1953. Most of the work was confined to the area between Priest Rapids and Paterson, a section which includes the Hanford Works of the Atomic Energy Commission and McNary Reservoir, an impoundment placed in operation in late 1953. Limited studies were also made in Roosevelt Lake, Bonneville Reservoir, and the areas around Portland and Astoria, Oregon.

The principal objectives of the survey were to determine: (a) the water quality characteristics of the stream prior to impoundment and (b) effects of radioactivity on the physical, chemical, and biological characteristics of surface waters. The studies have also provided data which can be used to establish stream sanitation objectives for developing comprehensive water pollution control programs and provided an opportunity for scientists to obtain experience in stream surveys where radioactive wastes are involved.

FINDINGS AND CONCLUSIONS

The findings and conclusions reached are as follows:

1. The Columbia River waters in the Priest Rapids to Paterson section are of very good quality except for minor domestic pollution in the Pasco-Kennewick area and at the mouths of the tributaries. This section is used principally as a source of reactor cooling water for the Hanford Works of the Atomic Energy Commission, public water supplies, irrigation, and recreation.

   The hydrological, physical, chemical, and bacteriological characteristics, applicable at Range C-362 (Hanford Ferry Crossing) unless otherwise stated, are given below:

   a. Stream flows follow a seasonal pattern, with high flows of about 300,000 to 500,000 c.f.s. occurring between May and July, and flows of 50,000 to 70,000 c.f.s. occurring during the remainder of the year. Tributary flows follow a similar pattern, but with peak runoff occurring about a month earlier.

   b. The water in the main stem is quite clear, with average turbidity values of less than 7 p.p.m., except during high flow periods. Tributaries are somewhat more turbid and have some effect on the main river.

   c. Water temperatures vary by seasons, from a low of 2°C. in February and March to a high average, for a cross section, of 20°C. in the late summer and early fall. Tributary values are slightly higher, with maximum values reaching 24°C.

d. Dissolved oxygen values are at or near saturation the year-round. Slightly lower concentrations are found in the tributaries, especially during low-flow periods.

e. The pH-values vary from 7.6 to 8.2, and alkalinity values from 51 to 8[illegible] p.p.m. Elsewhere in this section the alkalinity is generally under 100 p.p.m. Corresponding values for the tributaries are somewhat higher.

f. Mineral analyses show concentrations of the principal elements to be generally lower than would be of importance from the pollutional or toxicity standpoints.

g. The coliform MPN index for the entire section varies from <3.6 to 4,600 per 100 ml. The higher values are found below the Pasco-Kennewick area and the tributaries. Primary sewage treatment plants have been placed in operation at these two cities since the completion of these studies.

h. Generally speaking, the physical and chemical conditions in both the main stem and the tributaries are well within limits favorable to the support of a good mixed aquatic biota.

2. Plankton in the Columbia River is principally phytoplankton, with diatoms making up over 90% of the populations. The principal genera present are Asterionella, Cyclotella, Fragilaria and Synedra. Asterionella and Cyclotella occur in definite pulses, Asterionella being predominant in the spring months and Cyclotella in the late summer and fall months. The tributaries are responsible for the pulses of Cyclotella.

3. Bottom animals consist primarily of clean water forms such as mayfly nymphs, midgefly and caddisfly larvae and mollusks. Average numbers and weights show very little variation between ranges. The river is average to rich in fish food organisms. The tributaries contain similar organisms but somewhat larger numbers and weights, with average values about twice those in the main river.

4. Fish populations consist of both cold and warm water species. The major game and food fish are migratory species, such as chinook and blueback salmon and steelhead trout, and resident species, such as black bass, sturgeon and whitefish. Some spawning of chinook salmon occurs in the Hanford Works Reservation. Other species, mostly rough and forage fish such as suckers, carp, shiners and dace, are quite abundant. No commercial fishing is carried out within the Priest Rapids - Paterson area, but a large amount of sport fishing is done in this section. Fairly extensive commercial fishing is carried out in the lower river from Bonneville Dam to the mouth, mostly for salmon.

5. The major effluent entering the Columbia River in the Priest Rapids - Paterson section results from the cooling of the Hanford Works reactors. This discharge is thermally hot as well as being radioactive. The maximum and average gross beta activity densities for various types of samples at Range C-362 were,

Water:	19	and	6×10^{-6}	μc/ml
Plankton:	80,000	and	$20,000 \times 10^{-6}$	μc/gm
Filamentous algae:	13,000	and	$6,000 \times 10^{-6}$	μc/gm
Caddisfly larvae:	10,000	and	$7,000 \times 10^{-6}$	μc/gm
Juvenile fish (shiners):	9,000	and	$1,300 \times 10^{-6}$	μc/gm
Adult fish (suckers)				
Bone:	5,000	and	$1,200 \times 10^{-6}$	μc/gm
Muscle:	1,100	and	300×10^{-6}	μc/gm

The highest gross beta activity density values for water and various aquatic organisms are found at Range C-362, with a fairly sharp decrease at Range C-339 and a progressive decrease at downstream ranges. Values at Range C-278 are normally about one-tenth of those at Range C-362. A measurable amount, somewhat higher than background, remains to the mouth of the river, at Astoria, Oregon. Average background values are at or below 1×10^{-6} μc/gm. for aquatic organisms and 1×10^{-8} μc/ml. for water.

6. The radioisotopes are created by the neutron bombardment of dissolved and suspended materials in the cooling water, and consist principally of short half-lived beta particle emitters such as Cu^{64}, Mn^{56}, Na^{24}, As^{76}, Si^{31}, and P^{32}. Little or no alpha activity is present. Some of the radioisotopes in water are absorbed or concentrated in aquatic organisms. In certain organisms total beta activity density may be several thousand times that in water, while an individual isotope may be concentrated to an even greater extent. The principal radioisotope concentrated in aquatic organisms is P^{32} (half-life = 14.3 days), which is responsible for 90 per cent or more of the activity in river fish but less than 2 per cent of the activity in water. Some shorter half-lived materials, such as Na^{24}, Cu^{64}, Mn^{56}, Si^{31}, and As^{76}, are the principal ones absorbed and adsorbed by plankton.

7. The accumulation of radioactive materials by aquatic organisms follows a definite pattern. Plankton (mostly phytoplankton) and filamentous or attached algae, which absorb nutrients directly from the water, concentrate the largest amounts. Next are bottom animals which feed on this material, and then juvenile fish which feed on these animals. At the end of the chain are the adult fish which feed on the juveniles. There are exceptions to this general

chain. For example, some fish may feed directly on plankton, filamentous algae, or bottom animals.

8. The variations in activity levels in the Columbia River water are due primarily to changes in quality and quantity of cooling water discharges, to dilution during seasonal high river flows, and to natural decay. The maximum values are normally about five times less during periods of high river flows.

9. Activity levels in plankton and attached algae are directly dependent on levels in the river water.

10. Activity levels in aquatic animals are dependent upon their metabolic rates (which are in turn dependent upon water temperatures) and the activity of the material upon which they feed. The maximum activity density values in aquatic animals occur during low water stages and high water temperatures, usually in the late summer and fall months.

11. Migratory fish such as salmon, the adults of which do not feed while in fresh waters, have very low activity levels at the same time that levels in actively feeding species such as suckers, bass, and whitefish are high.

12. Radioactive materials are concentrated in all parts of the body of the fish. The activity levels, however, are about ten times higher in scales, bone, and internal organs than in the edible parts such as muscle or skin.

13. Insofar as could be determined there are no definite effects yet apparent on the physical, chemical, or bacteriological characteristics of this river as a result of the discharge of reactor effluents. While some of the effluents are thermally hot the magnitude of river flow is such that no overall temperature change is detectable.

14. There is no measurable effect on aquatic populations due to the levels of activity found during this survey. The fact, however, that river organisms concentrate specific isotopes, such as P^{32}, to levels many times those found in water and that some of these organisms, such as fish, are utilized to a large degree by humans, is of potential public health significance.

15. Radioactivity densities of river water and aquatic organisms have increased in the last several years. The isotopes concentrated have short half-lives and there is practically no build-up or carry-over from year to year.

16. Limited studies show that water treatment plants can remove some radioactive materials present in Columbia River waters. At Pasco, Washington, it was found that normal treatment by coagulation and filtration reduced the activity levels of the influent by 50 to 95 per cent.

17. On the basis of limited studies on existing Columbia River reservoirs, it is indicated that impoundment has some influence on physical, chemical, and biological characteristics. The effects apply principally to conditions within the reservoir but may have some influence on downstream waters. The major changes occur in large, deep storage type reservoirs such as Roosevelt Lake and may include:

    a. A decrease in current velocity with a corresponding decrease in silt loads below the reservoir.

    b. A possible increase in water temperatures but with little or no thermal stratification.

    c. Some change in chemical characteristics in the deeper waters such as a decrease in oxygen saturation, some increase in carbon dioxide with a corresponding decrease in pH values and a slight increase in iron and manganese concentration.

    d. A change in plankton populations which may build up seasonally and have some effect on downstream water uses.

    e. A definite change in bottom animals to types less desirable from the fish food standpoint.

    f. A change in fish populations with an increase in rough and forage species and a decrease in food and game species, especially where high dams without adequate fish passage facilities cut off migratory species such as salmon and steelheads.

    g. A general decrease in biological productivity, mainly from large winter drawdowns.

    The effects of "run-of-the-river" type of impoundments are much less pronounced, the major effects being from silt deposits, a change in bottom fauna and some changes in fish populations.

18. Radiological studies at Bonneville Reservoir indicate little or no effect on radioactivity levels by this type of impoundment. Since this reservoir is 150 or more miles below the Hanford Works most of the short half-lived materials have decayed to low levels and the major isotope remaining is the longer half-lived P^{32}. As the retention time of the water in Bonneville is relatively short there are no noticeable effects on radioactivity levels in water and aquatic organisms. It is possible that a reservoir much closer to the sources of radioactivity, such as McNary, will have some observable effects. The increased retention time will allow for more decay of short half-lived isotopes and will also allow more settling of silts and aquatic organisms which carry radioactive materials. Thus the radioactivity in waters below the reservoir will be reduced, but with a corresponding increase in the muds and aquatic organisms within the new reservoir.

RECOMMENDATIONS

The observations and findings from these studies indicate a need for continued or new work, as follows:

1. Sufficient data have been developed for use as a baseline to determine changes in water quality which may occur in the Priest Rapids to Paterson section, as well as in other relatively unpolluted areas. The entire basin is undergoing rapid development from the standpoint of power, industry, irrigation, and recreation. These developments should be carefully followed, along with changes that may occur in river conditions, to assure retention of the good water quality now found in so many locations.

2. While certain predictions regarding the effects of impoundments can be made, on the basis of limited studies in existing reservoirs, follow-up studies are needed. McNary Reservoir, with the baseline data available, offers an opportunity to follow the natural changes in water quality characteristics which will occur after the impoundment is in operation.

3. In recent years the trend of activity densities has been upward. Since present levels in water and aquatic organisms are many times above background, the routine monitoring program should be continued. The program, as at present, should include the river, the finished water at Kennewick and Pasco, and the operation of water treatment facilities at these municipalities.

4. Efforts should be continued toward the reduction of the amounts of radioactive materials that enter the river from atomic energy installations, especially for those radioisotopes which are concentrated to a high degree by aquatic organisms.

5. As resident adult fish concentrate more radioactive isotopes than migratory species, increased emphasis should be placed on studies of populations, migrations, and reproduction of resident species, as well as their use by humans. From the public health standpoint these studies are deemed to be more important than studies on migratory species, especially those which accumulate little or no radioactivity in the waters involved.

6. Studies should be continued on the uptake of radioactive materials by waterfowl and other animals that may utilize the waters or use aquatic organisms for food.

7. As salmon spawn within the Hanford Works area, studies should be continued on the genetic and other effects on these fish from radioactivity, with increased attention given to the possible effects from chemical toxicity.

8. Laboratory research on the effects of individual radioisotopes on aquatic life, including the amounts that may be deposited in fish and other organisms, should be expanded.

9. Further studies are needed on the effectiveness of water treatment plants in the removal of radioactive materials from waters which are to be used for domestic consumption. Such studies should include the problem of disposing of sludges and other waste products which may contain radioactive materials.

10. There is a definite need for improving and simplifying radiochemical analytical techniques and counting instruments for more accurate determination of low levels of activity.

CHAPTER II

GENERAL INFORMATION

In the accumulation of data on waters throughout the nation, it was found that more extensive knowledge was needed on the characteristics of the Columbia River from at least two standpoints: (a) for determining the effects of impoundments, several of which were proposed or under construction, and (b) from the standpoint of the effect of radioactive wastes on the normal stream purification factors. The principal study area selected included the Columbia River and tributaries from Priest Rapids to Paterson, Washington, and provided a natural site for examination of the stream from both standpoints. The upper reaches of the section were (and are) relatively unpolluted and offered an opportunity to take inventory of the chemical, bacteriological and biological characteristics of a Western surface stream in good condition. The lower reaches permitted a complete inventory prior to an impoundment and also below possible sources of pollution.

The installation of impoundments results in the development of industrial sites, especially where additional power becomes available, and also the development of recreational areas. In the semi-arid regions the increased availability of water for irrigation purposes brings about the development of agricultural areas. Thus a variety of interests must be served. In many cases the interests of one group are in conflict with those of another. To serve all of the interests effectively basic inventories are necessary.

From the standpoint of the effect of radioactivity the interest of health and other agencies was recognized. Eventually, as the expanding use of radioactive isotopes continues, the responsibility of protecting the general population against harmful effects of ionizing radiation will fall upon public health officials.

The Atomic Energy Commission and the General Electric Company, the present operating contractor at Richland, have a real interest in using the river as a source of industrial water supply and also for disposal of mildly radioactive cooling water from the nuclear reactors. They have, therefore, an understandable concern as to the possible effect of proposed multiple purpose impoundments of the river, lest changes in the characteristics of the waters have an unfavorable influence on plant operations. In addition, the joint interests of the States of Washington and Oregon as to the present and future uses of the river were also an important consideration.

A continuous program for controlling the discharge of radioactive wastes to the Columbia River has been in effect since the start of plant operations in 1944. This program, carried out by the prime contractors at the Hanford Works, has included not only the control of waste discharges but also the monitoring of the river within and adjacent to the AEC reservation.

In addition to the above program the Atomic Energy Commission in 1948 appointed the Columbia River Advisory Group, comprising representatives from the States of Oregon and Washington and from the U. S. Public Health Service. Its purposes are to keep abreast of plant operations as they relate to pollution of the Columbia River and to serve as a liaison between the Commission and the people of the States.

In carrying out these studies full cognizance was taken of the work which had been done or was in progress. It was felt that a certain amount of overlap was both desirable and advantageous. Since the General Electric Company and the Public Health Service were carrying out work which in some aspects was similar, the duplication of effort in a few cases enabled both to compare methods, procedures, and techniques.

OBJECTIVES

The main objectives of the Public Health Service program were as follows:

1. To ascertain the hydrological, physical, chemical, bacteriological, biological, and radiological characteristics and inter-relationships of the Columbia River before impoundment by McNary Dam. This would provide basic data of value in predicting the effects of this and other impoundments which have been proposed for the Columbia River Basin, and also assist in developing information that will be useful in the nation-wide program of the Public Health Service.

2. To develop new and to improve existing techniques as applied to stream sanitation objectives for use in developing comprehensive water pollution control programs.

3. To acquire knowledge of the effects and rate of recovery from the effects of radioactive wastes on the physical, chemical, and biological characteristics of surface waters.

4. To obtain and analyze data needed to establish stream sanitation objectives, including conditions where radiological wastes are involved, for use in developing comprehensive water pollution control programs.

5. To train personnel in the stream pollution phases of radiological health through experience in this type of activity as well as through association and cooperation with local groups.

INITIATION OF THE STUDIES

The general program for the survey of the Columbia River was discussed at a joint meeting with representatives of the U. S. Atomic Energy Commission, the General Electric Company, and the Public Health Service, and members of the Columbia River Advisory Group, held in Richland, Washington, on June 19 to 21, 1950. Although no definite areas of endeavor were discussed it was agreed that the Service would assign a few people to Richland to work with the local groups and develop a program acceptable to all agencies. Five persons were thus assigned between November 1950 and April 1951, and a more complete program developed.

A detailed proposal was presented at a meeting of the Columbia River Advisory Group held in Richland on May 21 and 22, 1951. The Advisory Group, as well as the representatives of the Atomic Energy Commission and General Electric Company, agreed to the program.

Sampling of the Columbia River and tributaries was begun on a limited scale on July 23, 1951, when a few samples were taken for chemical analyses. All parts of the program, covering the chemical, biological, bacteriological, and radiological sampling and analyses, were under way by September 26, 1951.

The regions included in this study are shown in figure 1. The principal study area covered the Columbia River and tributaries from Priest Rapids to Paterson, Washington. In addition, brief surveys were also conducted in (a) Roosevelt Lake, the impoundment behind Grand Coulee Dam; (b) the section between Wenatchee and Vantage, Washington, immediately above the Hanford Works; (c) the Bonneville Reservoir; (d) the section between Corbett and Portland, Oregon; and (e) the mouth of the Columbia River.

SAMPLING PROGRAM

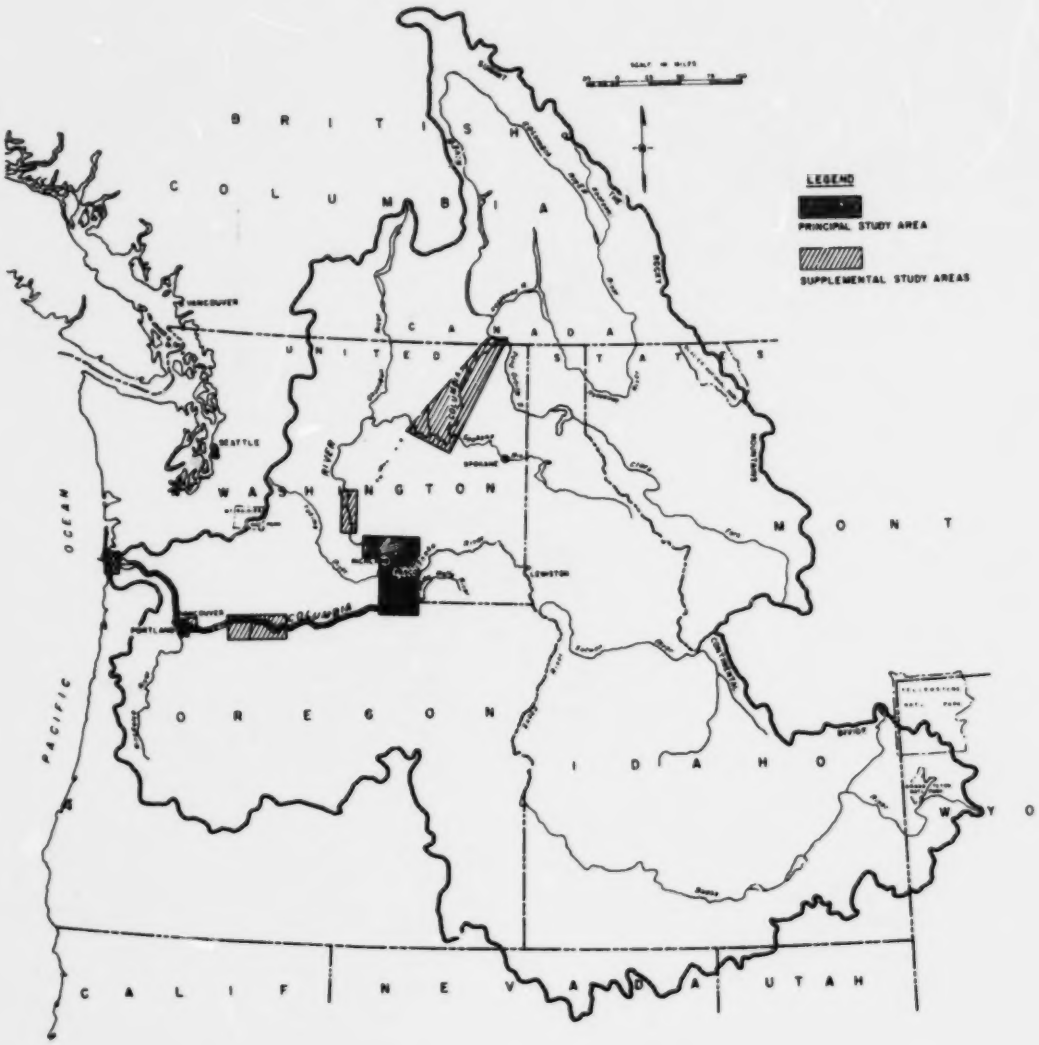
Sampling ranges were established in the principal study area, as shown in figure 2, so located as to detect the influence of the reactors and other variables such as tributaries, population centers, and impoundments. Biological samples were generally collected in shallow regions near the shore while water samples were taken at 3 to 10 points across the stream at each range. After a short period of sampling it was evident from the analytical results that such samples needed to be taken from only 5 points at most cross-sections in order to obtain representative data. Most water samples for chemical determinations were taken at mid-depth, while those for bacteriological examinations were taken just below the surface. It was soon realized that, because of the swift currents and turbulence in the Columbia River, depth was not a factor in obtaining representative samples except immediately below plant outlets.

A river mileage index system was established early in the work in order to clarify the location of sampling ranges and points. The system utilizes one or more letters to denote the stream or tributary and a number to denote the mileage from a fixed reference point. This system will, it is believed, permit correlation of future studies in any part of the drainage basin, either on the main stem or on a tributary, without necessitating changes in nomenclature. The fixed reference point used lies at the mouth of the Columbia River, and was established by the U.S. Corps of Engineers.

Collections of water samples for chemical and radiological analyses were carried out on a four-days-per-week basis. Ranges above and within the Hanford Works Area were sampled twice a month while those below the reservation were sampled weekly. Biological samples were, in general, collected at bi-weekly or monthly intervals.

LABORATORY ACTIVITIES

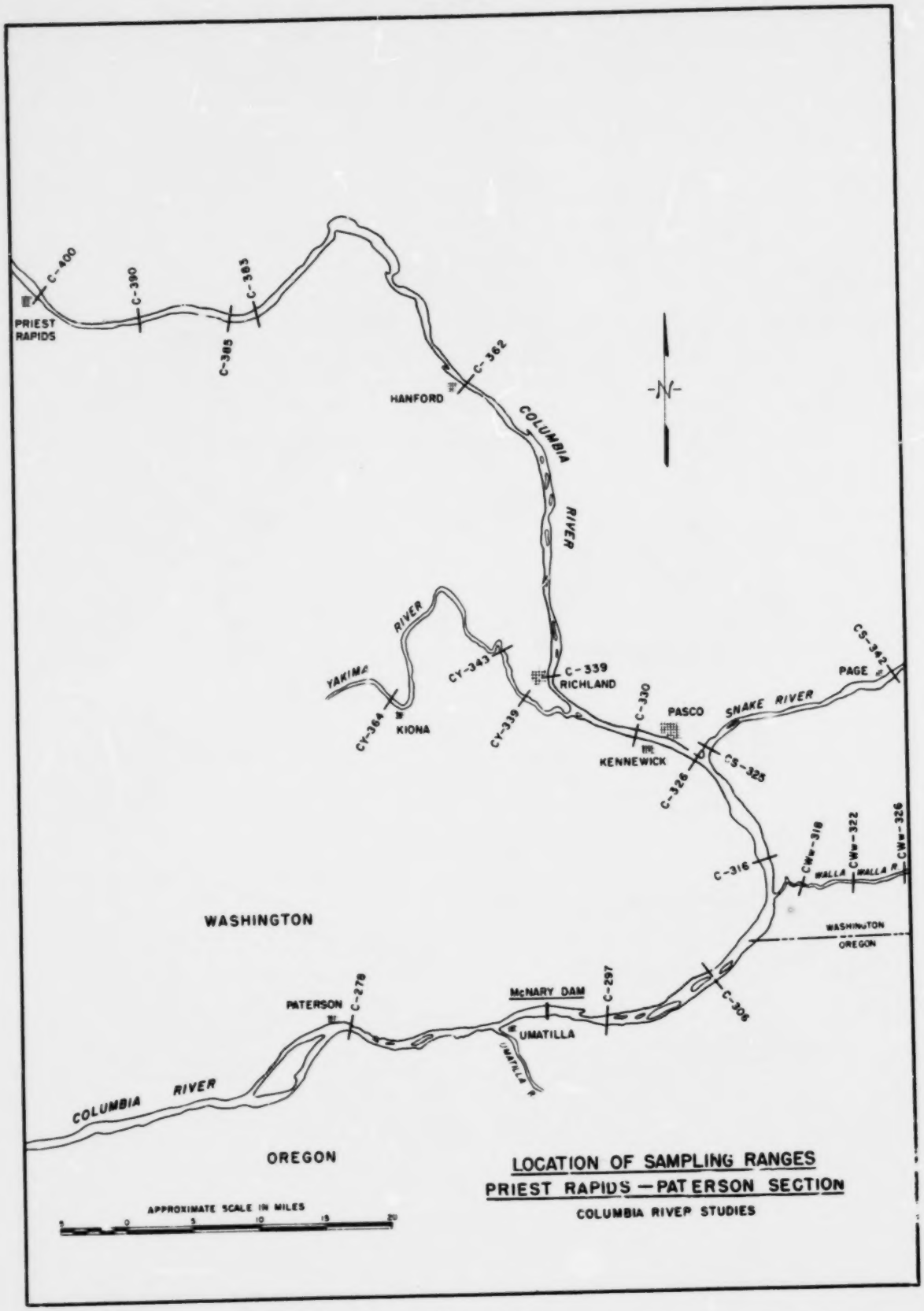
Initial laboratory operations were carried out in three mobile trailer laboratory units. A fixed laboratory was later established within the Hanford Works Area and operations transferred from the mobile units on December 17, 1951. Due to delays in setting up radiological counting facilities the General Electric Company Radiological Sciences Department provided radioactivity counting services during the early part of the studies, with samples being prepared by Public Health Service personnel.



COLUMBIA RIVER STUDIES
1951 - 1953

REGIONAL MAP

Figure I



LOCATION OF SAMPLING RANGES
PRIEST RAPIDS — PATERSON SECTION
COLUMBIA RIVER STUDIES

Figure 2

The staff numbered up to a maximum of 11 persons, and included 3 Sanitary Engineers, 3 Chemists, 3 Biologists, 1 Physicist, and 1 Clerk-Stenographer.

SUPPORTING STUDIES

From August 19 through 29, 1952, a study was made in the area between Bonneville Dam and The Dalles, Oregon. Five sampling ranges were established within the reservoir area, with a control station near The Dalles, Oregon, above the reservoir. Samples for chemical, bacteriological, biological and radiological analyses were collected at these stations.

During the period September 22 to 30, 1952 a study was made in Roosevelt Lake, the impoundment behind Grand Coulee Dam. The survey was intended to determine general ecological conditions, and covered mainly the determination of plankton and bottom fauna, simple chemical analyses and the determination of mineral constituents. Stations for the collection of chemical, biological, and bacteriological samples were established within the reservoir, as well as in the Spokane and Pend Oreille Rivers near their entrances into Roosevelt Lake.

Additional studies were made in Roosevelt Lake during April 1953, at a period when water levels were at a minimum. The type of sample and the sampling locations were essentially the same as in the earlier survey.

In cooperation with the General Electric Company and the Richland Rod and Gun Club, a bass transplanting program was carried out during the period of these studies. The objectives of this program were to develop information on the spawning habits, movements and growth of a resident game fish.

A limited number of bottom mud samples were collected in the Priest Rapids - Paterson Section and the Bonneville Reservoir for determination of alpha and beta activity densities.

CHAPTER III

GENERAL DESCRIPTION

The Columbia River Basin lies in an area of the United States which is filled with great potentialities and capable of considerable development. Irrigation systems will make much of its land agriculturally productive. Basic materials for industrial development are available from its mines and forests. The physical characteristics and descriptive features of the basin are therefore of some interest and are discussed below (1) (2).

THE COLUMBIA RIVER BASIN

The drainage basin covers a total area of about 259,000 square miles, of which 220,000 lie in the United States. This comprises some 7 per cent of the nation's land area and embraces most of Washington and Oregon, nearly all of Idaho, western Montana, and small portions of Wyoming, Utah, and Nevada.

The Columbia River originates in Columbia Lake, in the southeastern part of British Columbia, Dominion of Canada. It flows 190 miles northwest, thence generally south for about 270 miles to the international boundary. The river then continues for about 750 miles to its mouth, where it enters the Pacific Ocean. The total fall from source to tidewater is about 2,700 feet. Many of the tributaries, however, have even greater elevation drops between source and mouth, varying in some instances from 3,000 to 6,000 feet.

The principal tributary is the Snake River, draining an area covering approximately the southeastern half of the United States portion of the basin. Other major tributaries include the Pend Oreille, Spokane, Yakima, and Willamette Rivers. Numerous smaller tributaries also enter the Columbia River throughout its length.

TOPOGRAPHY AND GEOLOGY

The Cascade Mountain Range extends in a north-south direction, parallel to and at short distances inland from the Pacific Coast. Lying some 200 to 300 miles east of the Cascades and running in a northwest-southeast direction is the main range of the northern Rocky Mountains. Ninety-one per cent of the land area of the Columbia River Basin, accounting for 75 per cent of the runoff, lies between these (including both the United States and Canada).

A large plateau, narrow at the north and widening to the south, is enclosed by the two ranges. It has several low mountain ranges and rolling hills, with very steep and precipitous canyons in many places. Much of this area is composed of enormous sheets of horizontal lava flows, covered with surface materials suitable for a variety of agricultural purposes. Nearly all of the interior lands suitable for cultivation are in semi-arid or near-deserts.

The lower, drier mountain slopes and the dry, interior plateaus are covered by sagebrush and other desert vegetation. The surrounding humid mountains are covered with forests of varying types and densities. It has been

reported that these forests, together with those of the coastal area, contain the largest reserve of standing timber in the United States.

CLIMATOLOGY

From the hydrological standpoint the Columbia River Basin may be broken down into three divisions: (a) the region west of the crest of the Cascade Mountains; (b) the great central area east of the Cascade Range, comprising the Columbia Plateau in the north and the Snake River Plains in the south and southeast; and (c) the northern Rockies and mountain valleys in the northeast.

Nearly one-fourth of the total runoff in the basin comes from the region west of the Cascades, comprising less than one-tenth of the total land area. About half of the total flow comes from the northern Rocky Mountain section in the United States and Canada, consisting of slightly over one-fourth of the basin area. The central region, containing almost 60 per cent of the total basin area, contributes less than 30 per cent of the runoff.

Extremely wide variations in climatic conditions exist, due primarily to the influence of mountain ranges and of elevation. West of the Cascades, under marine influences, the climate is relatively mild, equable and humid, although the summers are dry. Climate east of the Cascades is more continental in character.

West of the Cascades, precipitation varies from about 40 inches annually in the valleys to 100 inches or more in the mountain areas. Extremes in limited lowland areas range from 15 to 30 inches, while in some small mountain areas over 200 inches of rain and snow fall annually. Precipitation east of the Cascades varies from about 6 inches in sheltered basins to 50 inches or more in high mountain areas. In the high mountain masses snowfall makes up a greater part of the precipitation.

Temperatures vary from about 10 to 100 degrees Fahrenheit along the coast and from minus 50 to plus 120 degrees Fahrenheit in the inland areas.

POPULATION

The population density is about 14 persons per square mile. Most of the inhabitants are concentrated in relatively small areas where physical conditions have favored the development of compact irrigated farming communities; in lumbering centers and mining communities; and in the relatively humid Willamette Valley. Wide expanses of the inner plateau regions support a relatively sparse population.

The population of the basin rose from about 2.2 millions in 1940 to about 3.2 millions in 1950. This is an increase of over 40 per cent as compared to an overall nationwide increase of about 15 per cent during the same period. Migration into the region accounted for much of the change.

LAND USE AND DEVELOPMENT

The economy of the area is dependent primarily on the production of food products and various raw materials. These include timber, grain, wood, livestock, fruits, fish, and minerals.

The major portion of the gainful employment in the basin can be traced to agriculture, with more than half of the total cultivated acreage being used for the production of small grain. Some irrigated areas produce such crops as sugar beets, potatoes, vegetables, and fruits. Livestock grazing also accounts for a sizeable portion of the land use.

The Columbia River Basin contains some 59 million acres of forests. The annual lumber yield is about 5.4 billion board feet, or 15 per cent of the nation's total. The value of the basin's mineral yield, though significant, is not large. The copper area around Butte, Montana, and the silver-lead-zinc district in northern Idaho are perhaps the most important. A large phosphate reserve of about 5 billion tons in the southeast corner of the basin is an important future potentiality.

Manufacturing is largely devoted to processing raw materials and agricultural products. Food processing plants, saw mills, paper and pulp mills, mineral processing plants, and electrochemical and electrometallurgical plants are the principal industries. These are widely scattered and generally situated close to the source of raw materials. Hydroelectric developments are also scattered throughout the region, although the most important ones are on the middle and lower Columbia River.

Private and rather small recreational developments are widely dispersed along the highways, lakes, and streams. Some of the nation's most spectacular and beautiful national parks are located within the basin. Several wilderness areas and other scenic attractions are in the national forests.

WATER USE AND DEVELOPMENT

The most important uses of Columbia River water are for power and irrigation. Also of importance, however, are the uses for domestic water supply, fishing, navigation, and recreation.

The steep gradient of the river and the large flows provide a very large hydroelectric power potential. Ten dams and power plants are proposed for eventual development of the main stream within the United States. Of these, Grand Coulee, Rock Island, McNary, and Bonneville Dams are completed and in total or partial operation. Chief Joseph and The Dalles Dams are under construction. The total present production for the entire basin is about 2,000,000 kilowatts, amounting to about one-sixth of the hydroelectric power capacity in the United States. Projects under construction or authorized will add about 3,000,000 kilowatts additional capacity.

About 3,800,000 acres of land are now being irrigated, of which nearly 70 per cent lie in the Snake River Basin. About 23 per cent of the total is above the confluence of the Snake and Columbia Rivers and the remainder below. A large irrigation project is now being developed in connection with the Grand Coulee Dam impoundment, a system designed to eventually irrigate about

1,000,000 acres in southeastern Washington. Proposed developments will add some 1.5 million acres of irrigated lands.

About 600 miles of waterways on the Columbia, Willamette, and Snake Rivers are presently navigable. Minimum depths of 27 feet are available as far as The Dalles, on the Columbia River, and into Portland at the mouth of the Willamette River. Shallow depths of 5 to 7 feet, suitable for barge traffic, are maintained on the Willamette River, to Albany, Oregon; and as far as Lewiston, Idaho, on the Snake River, about 275 miles above The Dalles. The principal traffic consists of upstream movements of petroleum products and downstream movement of wheat, logs, and lumber. In 1949 the total traffic passing Bonneville Dam, in both directions, was about 1,340,000 short tons. The corresponding figure at The Dalles was about 900,000 short tons.

About 1.5 million people are served by the 209 existing public water supplies, originating from both ground and surface sources. Surface sources account for 58 of the supplies, ground sources provide for 125, and a combination of the two account for the remaining 26. The combined daily consumption is over 100 million gallons. Industrial requirements are estimated to be several times this figure. From the standpoint of water quality, there appear to be very few, if any, problems that cannot be overcome by presently known treatment methods.

Much of the basin, especially below Rock Island Dam, is utilized for the propagation of commercial and game fish. Salmon and steelhead trout migrate up the watercourses to spawn and the young, in time, pass downstream to the Pacific Ocean. The river is one of the nation's most important commercial and recreational fishing streams. Cold water species, such as salmon and trout, are the basis for both a commercial and sport fishery. In Washington and Oregon the commercial value of the fish and fishery products from the Columbia River is reported to be over 18 million dollars per year.

In addition, many areas are used for wildlife, boating, bathing, and other recreational purposes.

CHAPTER IV

STREAM FLOWS

Information on stream flows and characteristics are available from many sources. Data used in this report were obtained from the U. S. Geological Survey, U. S. Corps of Engineers, and the General Electric Company.

For the purpose of these studies it was desirable to have not only the discharges but also to know the variations in river stages and the flow time between selected points.

DISCHARGE DATA

Monthly average discharges for the Columbia River and three important tributaries for the period 1930 to 1951, inclusive, are shown in figure 3.

Data for the main stream are taken from measurements made at Ground Coulee and at Bonneville Dams. The flow patterns at both locations are quite similar, showing little overall effect from the tributaries entering between these points. Flows generally begin to increase in April and reach a peak during May or June. There is then a decrease until September, with flows remaining fairly constant until March or April. High monthly average flows vary from about 220,000 to 530,000 c.f.s. at Grand Coulee Dam, and from about 275,000 to 845,000 c.f.s. at Bonneville Dam. Low monthly average flows vary from about 18,000 to 60,000 c.f.s. at Grand Coulee Dam, and from about 45,000 to 105,000 c.f.s. at Bonneville Dam.

The flow patterns in the tributaries differ somewhat from the main stream. The Snake River reaches peak flows in April or May, generally about a month before the Columbia River. High monthly average flows near Clarkston, Washington, nearly 134 miles above the mouth, varied from about 76,000 to 185,000 c.f.s during the period shown. Monthly average low flows are around 15,000 to 20,000 c.f.s.

Average high flows on the Yakima River, measured at Kiona, Washington, some 30 miles above the mouth, are usually under 20,000 c.f.s. High flows generally occur during May or June. Low flows, maintained between September and April, are about 5,000 c.f.s. or less.

The Willamette River, draining a region which lies west of the Cascade Mountains, differs from the Snake and Yakima Rivers. The occurrence of high flows varies, but normally takes place between December and March. High monthly average flows vary from 45,000 to 105,000 c.f.s. Low monthly averages are normally 5,000 c.f.s., or under, and generally occur during the late summer or early autumn months.

In order to more effectively correlate analytical results with river conditions it is desirable to know the daily stream conditions during the survey period. Figure 4 shows the daily river conditions in the Priest Rapids to Paterson Section for the period July 1, 1951 to June 30, 1953. The chart shows daily discharge and river levels near Hanford, Washington above McNary Dam, and the daily river levels near Umatilla, Oregon, below McNary Dam.

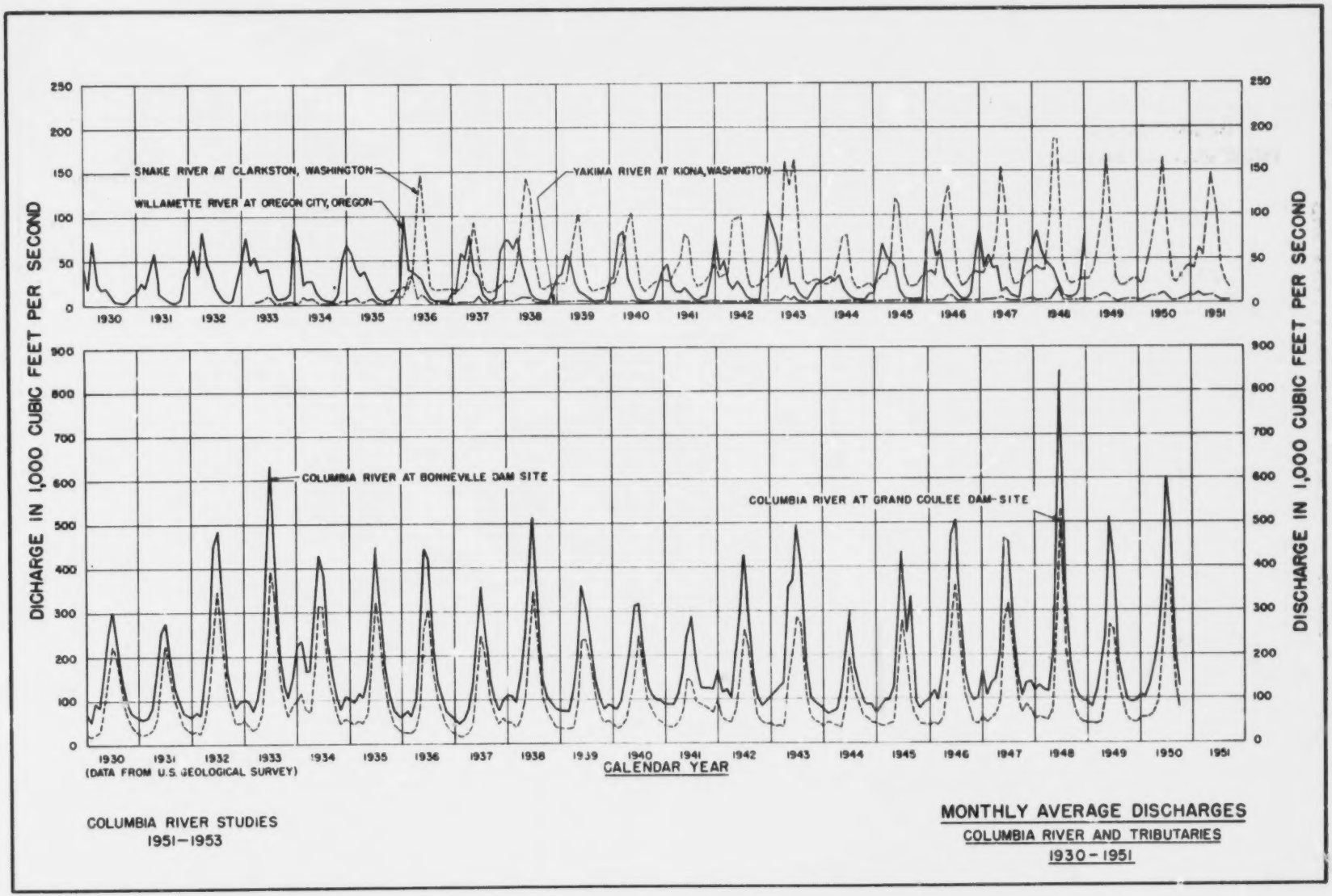
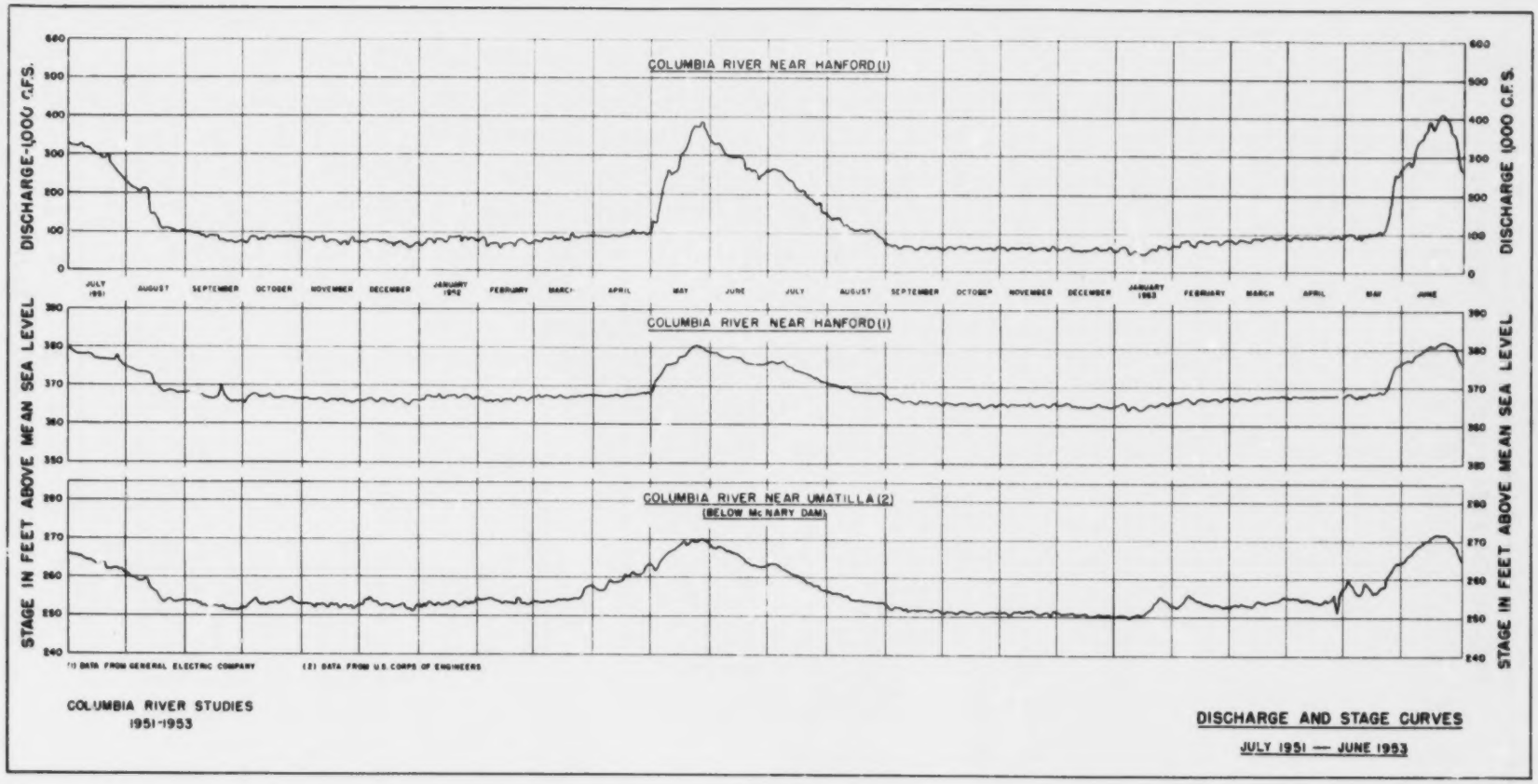

SNAKE RIVER AT CLARKSTON, WASHINGTON
WILLAMETTE RIVER AT OREGON CITY, OREGON
YAKIMA RIVER AT KIONA, WASHINGTON
COLUMBIA RIVER AT BONNEVILLE DAM SITE
COLUMBIA RIVER AT GRAND COULEE DAM-SITE
DICHARGE IN 1,000 CUBIC FEET PER SECOND
DISCHARGE IN 1,000 CUBIC FEET PER SECOND
CALENDAR YEAR
(DATA FROM U.S. GEOLOGICAL SURVEY)
COLUMBIA RIVER STUDIES
1951-1953
MONTHLY AVERAGE DISCHARGES
COLUMBIA RIVER AND TRIBUTARIES
1930-1951

Figure 3



COLUMBIA RIVER STUDIES
1951-1953

DISCHARGE AND STAGE CURVES

JULY 1951 — JUNE 1953

Figure 4

The daily discharge data bear out the observations made on the basis of monthly averages. The peak discharge for 1951 occurred at Hanford prior to July 1 of that year. The high flow occurred in late May in 1952 and during mid-June in 1953. The stage curves reflect the effect of the Snake River. Peak flows on this tributary, as has already been pointed out, occur about a month before those on the main stream. It will be noted that the main stream, below McNary Dam, begins the 1952 rise in late March, whereas at Hanford there is no appreciable rise until late April. In 1953 the corresponding events occur about a month later. The irregularity of the levels at Umatilla during late April and early May of 1953 was due to partial filling of the McNary Dam impoundment during that period.

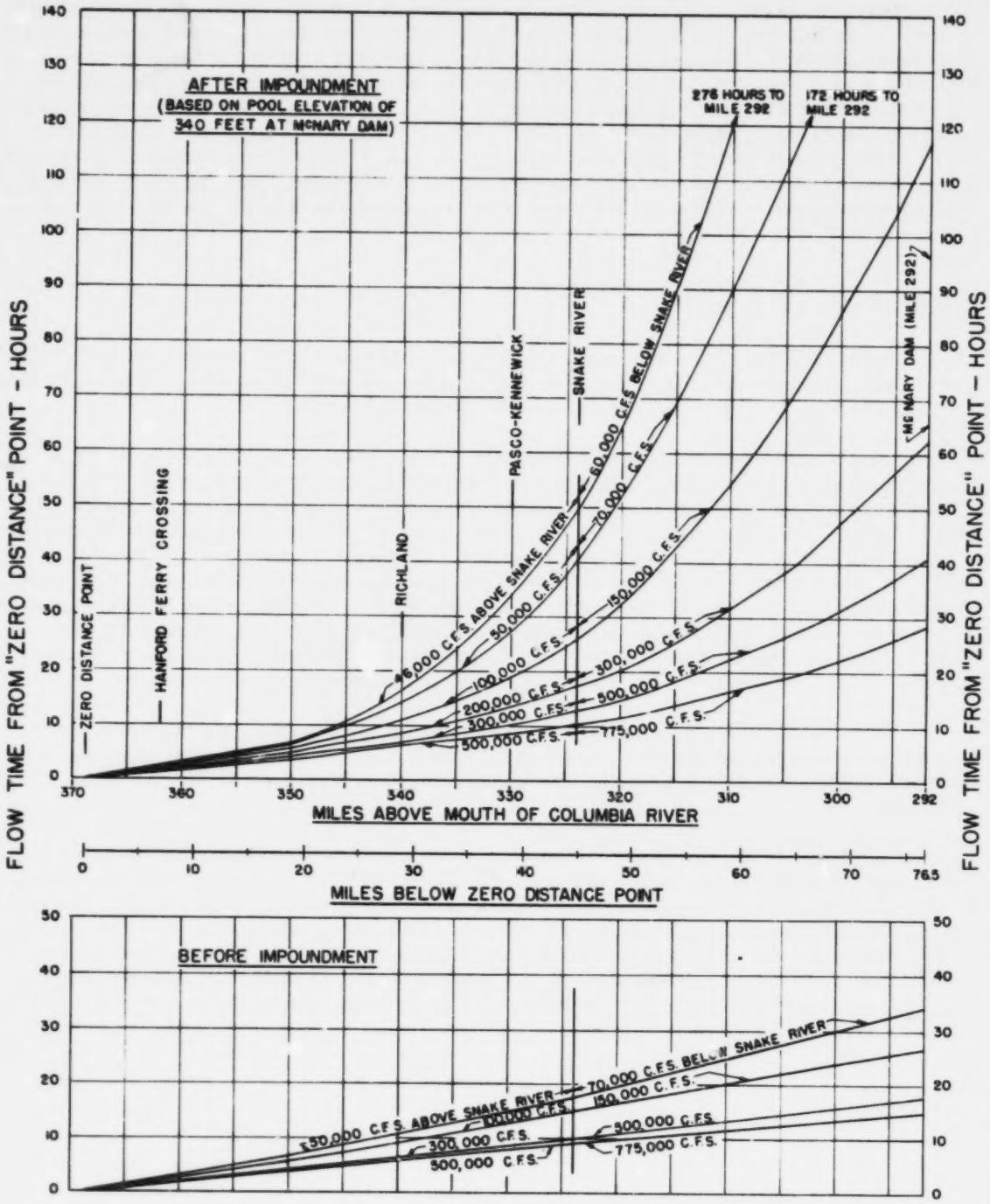
STREAM VELOCITIES

Velocity data are important from two standpoints: (a) for determining flow time between sampling ranges, and (b) for ascertaining the changes in flow time caused by increased runoffs and by impoundment.

A set of curves, figure 5, has been developed to show the flow time between various points and at several rates of discharge in the section between Hanford and Paterson, both before and after impoundment by McNary Dam. The "zero distance" point for these data is located near Hanford, below all reactor cooling water discharge points. These curves cover a range of flows varying from 46,000 to 500,000 c.f.s., above the Snake River. While the flows of the Yakima River are too small, generally, to influence these curves appreciably, such is not the case with the discharge from the Snake River. Hence, the portion of the curves for the section below the Snake River makes allowance for the expected contribution from this important tributary.

The flow time is based on average velocities between cross-sections spaced at 1 to 2 mile intervals. Information on river stages, discharges, and cross-sectional areas for these computations was obtained from the U. S. Corps of Engineers.

As would be expected, there is a considerable increase in the time of flow after the impoundment. The curves show that for a flow of 100,000 c.f.s. at Hanford the flow time to McNary Dam is about 27 hours before impoundment and 117 hours after the impoundment, or a difference of 90 hours. For a flow of 500,000 c.f.s. at Hanford the flow time is 15 hours before impoundment and nearly 29 hours after impoundment, or a difference of about 14 hours. Since discharges during the greater portion of the year are less than 100,000 c.f.s. the increase in flow time can be over 90 hours.



(BASED ON DATA FURNISHED BY U.S. CORPS OF ENGINEERS)

FLOW-TIME CURVES
COLUMBIA RIVER
MILE 368.5 TO MILE 292

Figure 5

CHAPTER V

CHEMICAL AND BACTERIOLOGICAL STUDIES

The routine physical and chemical examinations included those for turbidity, temperature, dissolved oxygen, biochemical oxygen demand, ammonia, nitrites, nitrates, phosphates, sulphates, chlorides, hydrogen-ion concentration (pH), methyl orange alkalinity and phenolphthalein alkalinity. During the first six months of sampling, the river flow remained fairly constant and the results of these analyses showed very little variation. This type of sampling was therefore reduced. With the occurrence of high water conditions in the spring months the routine sampling was resumed to determine the influence of increased flows. As the water stages returned to low levels, this type of sampling was again curtailed in the interests of other work.

In order to keep abreast of the chemical quality of the water, as related to the aquatic life, a chemical kit was assembled for making certain water examinations at the time and location of taking biological samples. The field examinations were limited to temperature, turbidity, dissolved oxygen, hydrogen-ion concentration and alkalinity.

Mineral analyses were made to determine the presence and availability of elements considered necessary for plant and animal metabolism, as well as those components which might possibly be toxic to these plants and animals. Samples were generally taken at 3 to 5 points on each range, and composited for the laboratory determinations. The principal elements usually considered necessary for plant and animal metabolism and utilized in substantial quantities by aquatic organisms are nitrogen, phosphorus, potassium, and calcium. Copper, iron, manganese, zinc, magnesium, and sulphur are also considered necessary, but are used in lesser quantities. Some of these elements may also be toxic if present in excessive amounts.

Laboratory analyses, in general, were made in accordance with the procedures given in Standard Methods, IX (3). Modifications were made in some methods to fit local conditions and these are given in Appendix A.

During the early period of the project, sampling of waters for bacteriological analyses was done at all main stream and tributary ranges. Samples were collected at 3 points on each cross-section. Later this phase of the work was curtailed, and sampling confined to the ranges between Richland and Paterson and to the mouths of tributaries, because the major portion of domestic wastes enter the streams in that part of the principal study area.

Bacteriological work was limited to determination of the M.P.N. Index, since it is the best indicator of domestic pollution. Three tubes in each of 3 dilutions were planted (1.0, 0.1, and 0.01 ml. were usually adequate) and incubated for 24 to 48 hours for the presumptive test. Samples showing gas formation were transplanted to brilliant green bile broth for confirmation.

CHEMICAL AND PHYSICAL EXAMINATIONS

Results of analyses of individual samples taken in the Priest Rapids - Paterson section are presented in Appendix B. The data are discussed and presented graphically below.

Turbidity

As shown in figure 6, the Columbia River, above the Yakima River confluence, was quite clear during most of the year (less than 7 p.p.m.) but became slightly turbid during the early part of the high water period. The turbidity in the downstream portions, especially during the summer months, was considerably affected by the condition of the tributaries. They are generally much more turbid than the main river, and fluctuations may be great due to heavy rains or excess irrigation water. The Snake River, the largest of the tributaries, is the major cause for the large turbidity fluctuations at the lower ranges in the main stream.

Temperature

Temperature fluctuations were primarily seasonal, as shown in figure 7. The readings at individual sampling points varied from a low of 2°C. in January and February 1952 to a high of 23°C. in August 1952, but the maximum average cross-sectional value was 20°C. Very little variation occurred between ranges, and this only in the lower ones due to the influx of somewhat warmer tributaries. Temperatures in the tributaries varied from 0° to 24°C.

To illustrate influence of the reactor coolant upon river water temperatures, figure 8 has been prepared to show the variation in temperatures across the width of the stream as well as above and below the reactors and tributaries. In general there is no significant increase due to the reactor coolant. However, on a few days in the winter of 1953 there was an increase of one degree Centrigrade at some points before mixing was complete.

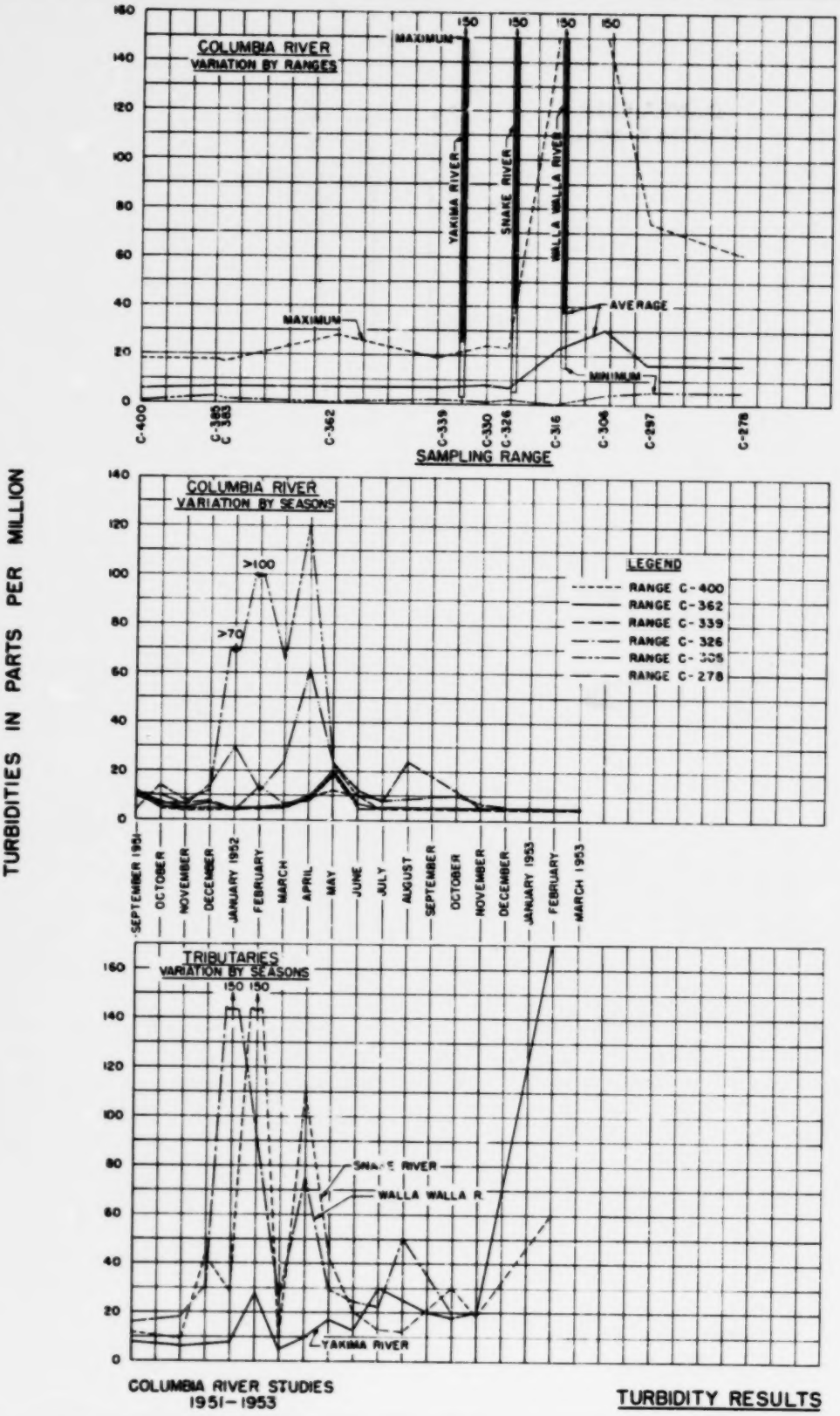
The average water temperatures during the winter of 1952-53 are 3 to 6 degrees higher than for the preceding winter. This can be attributed to the higher than normal air temperatures in this general area during that period.

Dissolved Oxygen

Fluctuations in dissolved oxygen, shown in figure 9, seemed to depend principally on temperature. A saturated condition was prevalent most of the time in the Columbia and Snake Rivers. The Yakima and Walla Walla Rivers have been known to fall below saturation values during periods of low flows and high irrigation usage, but oxygen concentrations are generally adequate to support aquatic life and maintain good stream conditions (4).

Biochemical Oxygen Demand

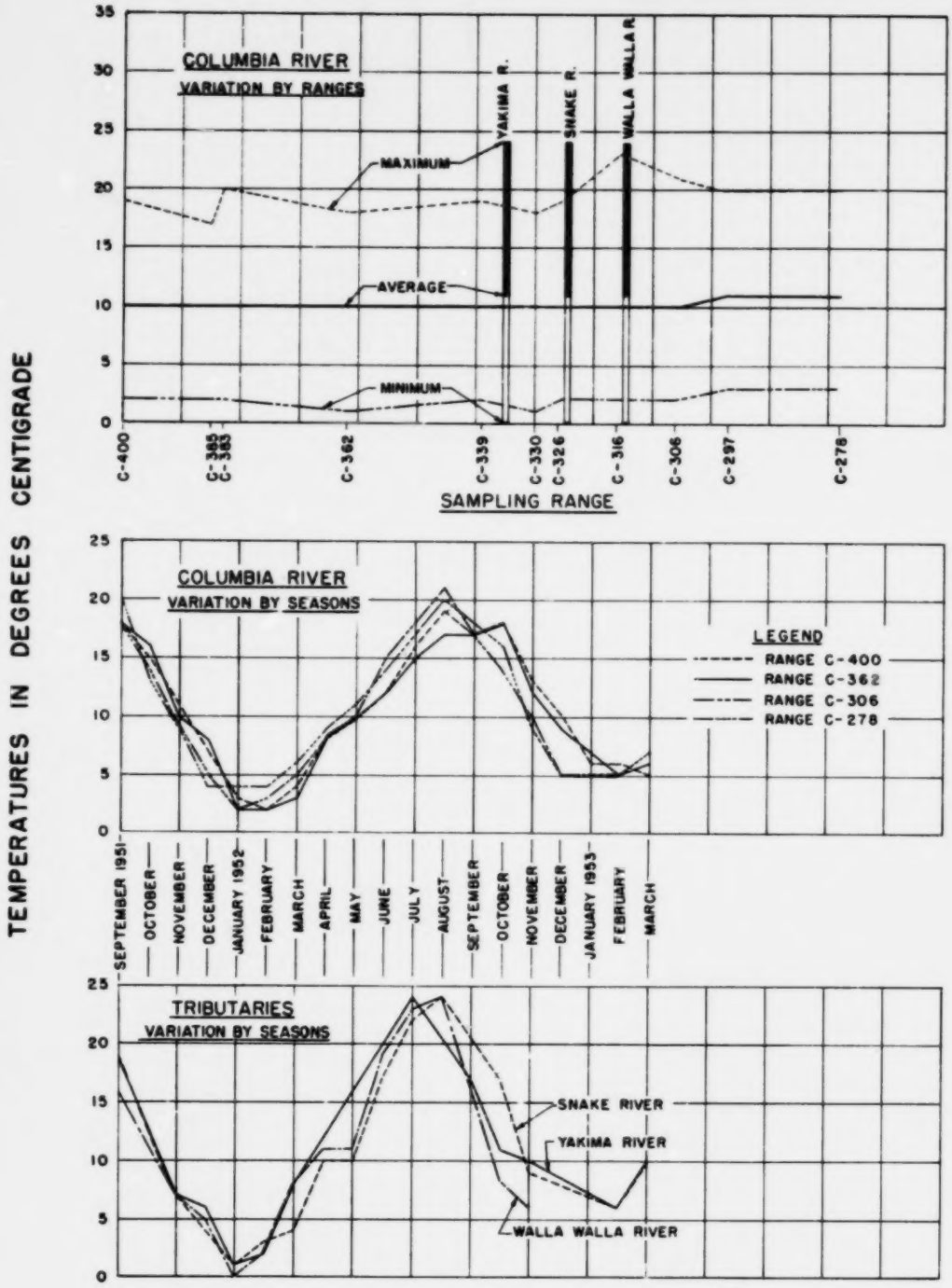
Biochemical oxygen demand values were generally less than 1 p.p.m., except in the Pasco - Kennewick area and in the tributaries. The maximum value found on the main stream was 2.9 p.p.m. and occurred between the Yakima and Snake Rivers. For the tributaries the maximum values found were 3.8 p.p.m. on the Yakima River, 2.6 p.p.m. for the Snake River, and 7.1 p.p.m. for the Walla Walla River.



COLUMBIA RIVER STUDIES
1951–1953

TURBIDITY RESULTS

Figure 6



COLUMBIA RIVER STUDIES
1951-1953

TEMPERATURES

Figure 7

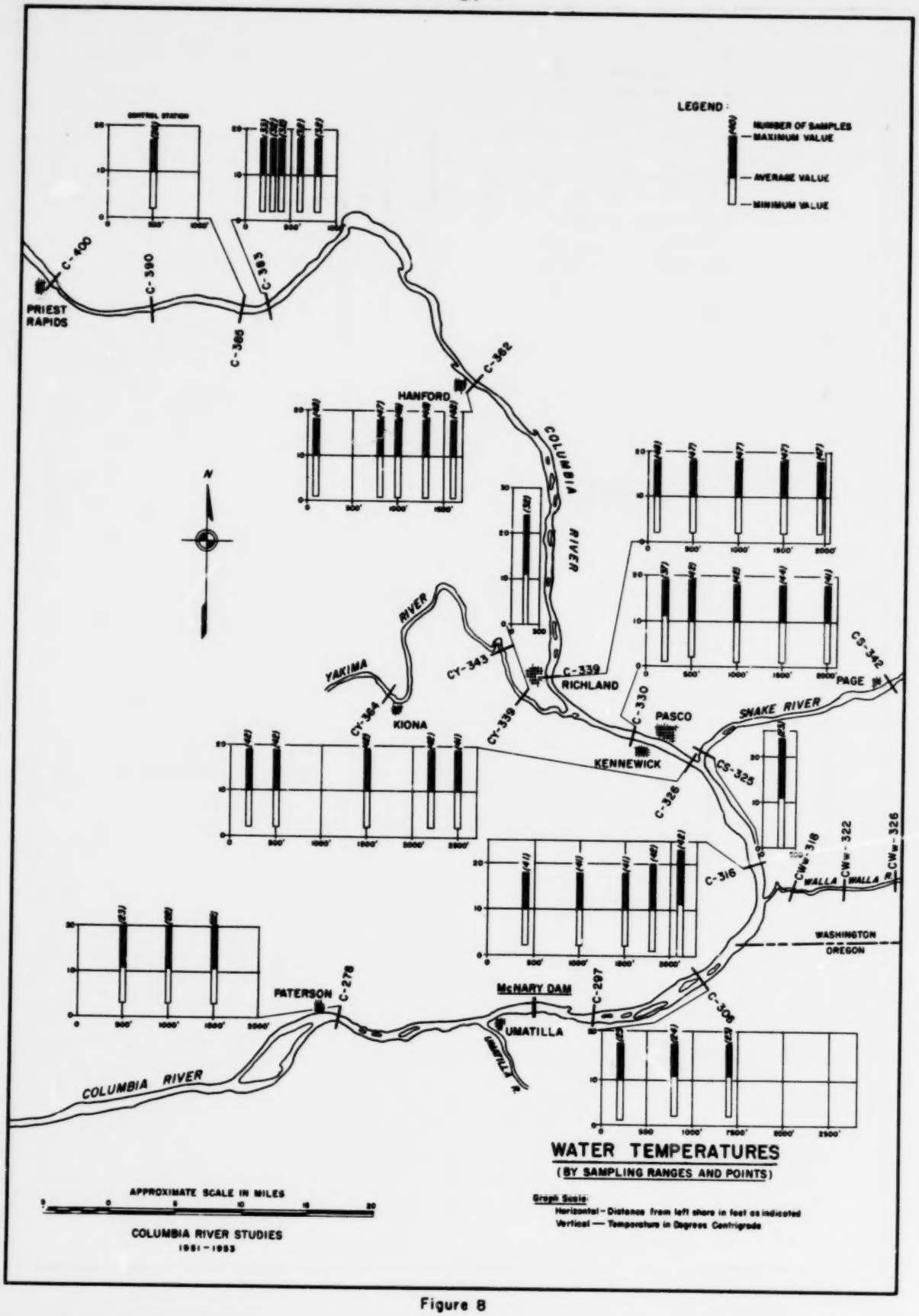
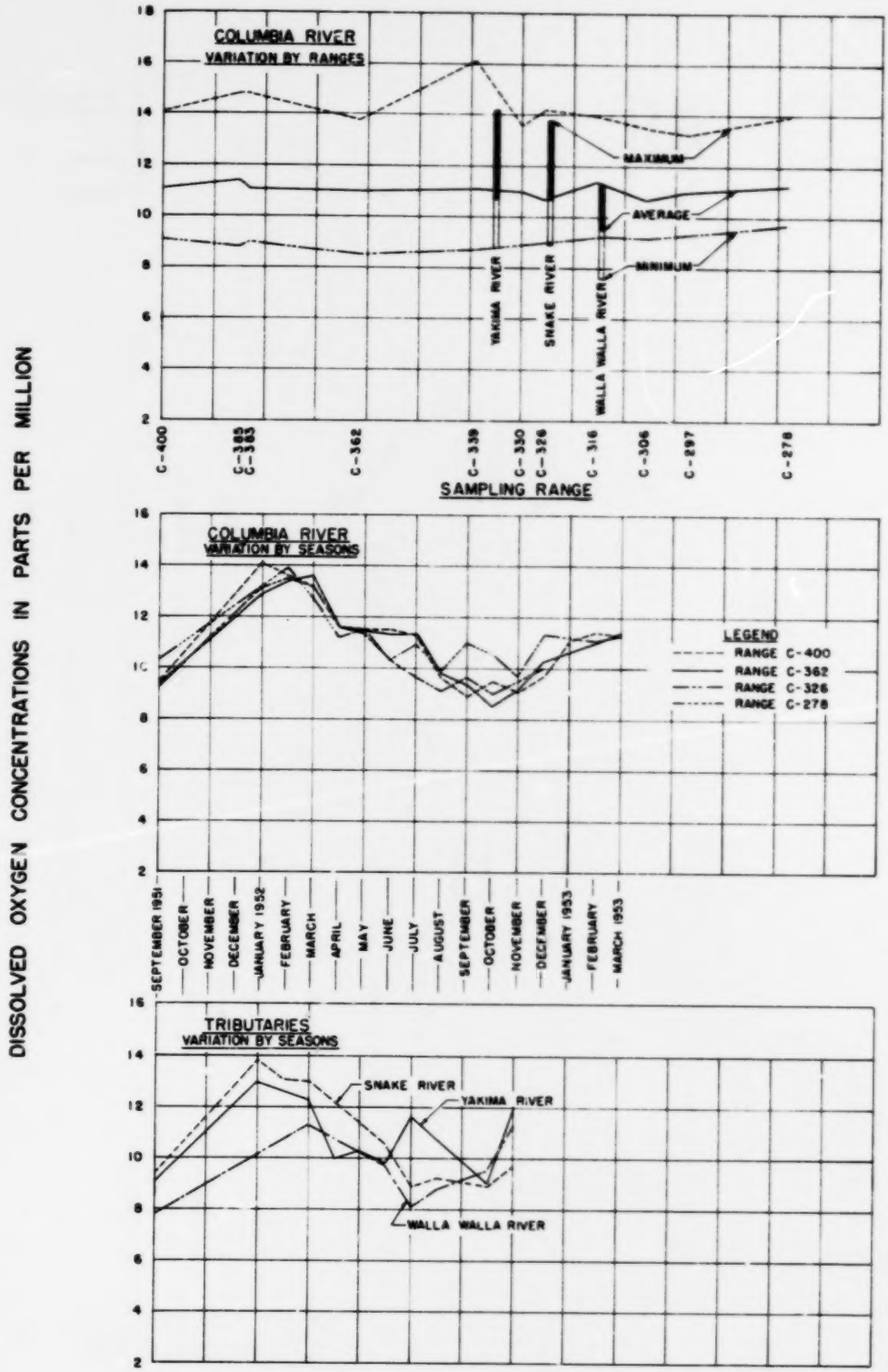

LEGEND:
NUMBER OF SAMPLES
MAXIMUM VALUE
AVERAGE VALUE
MINIMUM VALUE
CONTROL STATION
C-400
PRIEST RAPIDS
C-390
C-383
C-385
C-382
HANFORD
COLUMBIA RIVER
N
YAKIMA RIVER
CY-343
C-339
RICHLAND
CY-339
CY-364
KIONA
C-330
PASCO
KENNEWICK
SNAKE RIVER
CS-342
PAGE
CS-325
C-326
C-316
CWw-318
CWw-322
CWw-326
WALLA WALLA R.
WASHINGTON
OREGON
PATERSON
C-278
McNARY DAM
C-297
C-306
UMATILLA
UMATILLA R.
COLUMBIA RIVER
WATER TEMPERATURES
(BY SAMPLING RANGES AND POINTS)
APPROXIMATE SCALE IN MILES
COLUMBIA RIVER STUDIES
1951 - 1953
Graph Scale:
Horizontal - Distance from left shore in feet as indicated
Vertical — Temperature in Degrees Centrigrade

Figure 8



COLUMBIA RIVER STUDIES
1951- 1953

DISSOLVED OXYGEN

Figure 9

Determinations for biochemical oxygen demand were discontinued early in the survey because they were generally low while the oxygen content was high. Therefore, the scattered results have not been presented graphically but are tabulated in Appendix B.

Nitrogens

Determinations were made for nitrogen as ammonia, nitrite, and nitrate. Results in all cases were quite low in the section above the Yakima River, with an increase in maximum values below the mouth of this tributary. This is to be expected because of the discharge of sewage, both into the tributaries and the area below Pasco and Kennewick. The ranges of values found, in the various sections of the Columbia River and tributaries, are presented in table 1, below:

Table 1 - RESULTS OF NITROGEN ANALYSES

Location	Ammonia N ppm		Nitrite N ppm		Nitrate N ppm	
	Min.	Max.	Min.	Max.	Min.	Max.
Columbia River						
Above Yakima River	0.00	0.18	0.00	0.04	0.00	0.20
Below Yakima River	0.00	0.50	0.00	0.10	0.00	0.18
Yakima River	0.01	0.24	0.00	0.10	0.00	0.40
Snake River	0.00	0.96	0.00	0.03	0.00	0.30
Walla Walla River	0.00	0.28	0.00	0.07	0.01	0.05

Chlorides

Chloride values were generally under 1 p.p.m., except in and below the tributaries. Concentrations ranged up to 6 p.p.m. in the Yakima River, 16 p.p.m. in the Snake River and 28 p.p.m. in the Walla Walla River. The maximum value found in the Columbia River was 15 p.p.m., just below the Snake River.

Hydrogen-Ion Concentration (pH)

Hydrogen-ion concentration results are shown in figure 10. In the upper portion of the Priest Rapids - Paterson section there was a slight variation in results, due primarily to changes in river flows. In the lower reaches the pH was somewhat higher due to the influx of tributaries. Median values were around 8.1 at most locations, while the maximum did not exceed 9.0 and the minimum did not go below 7.5.

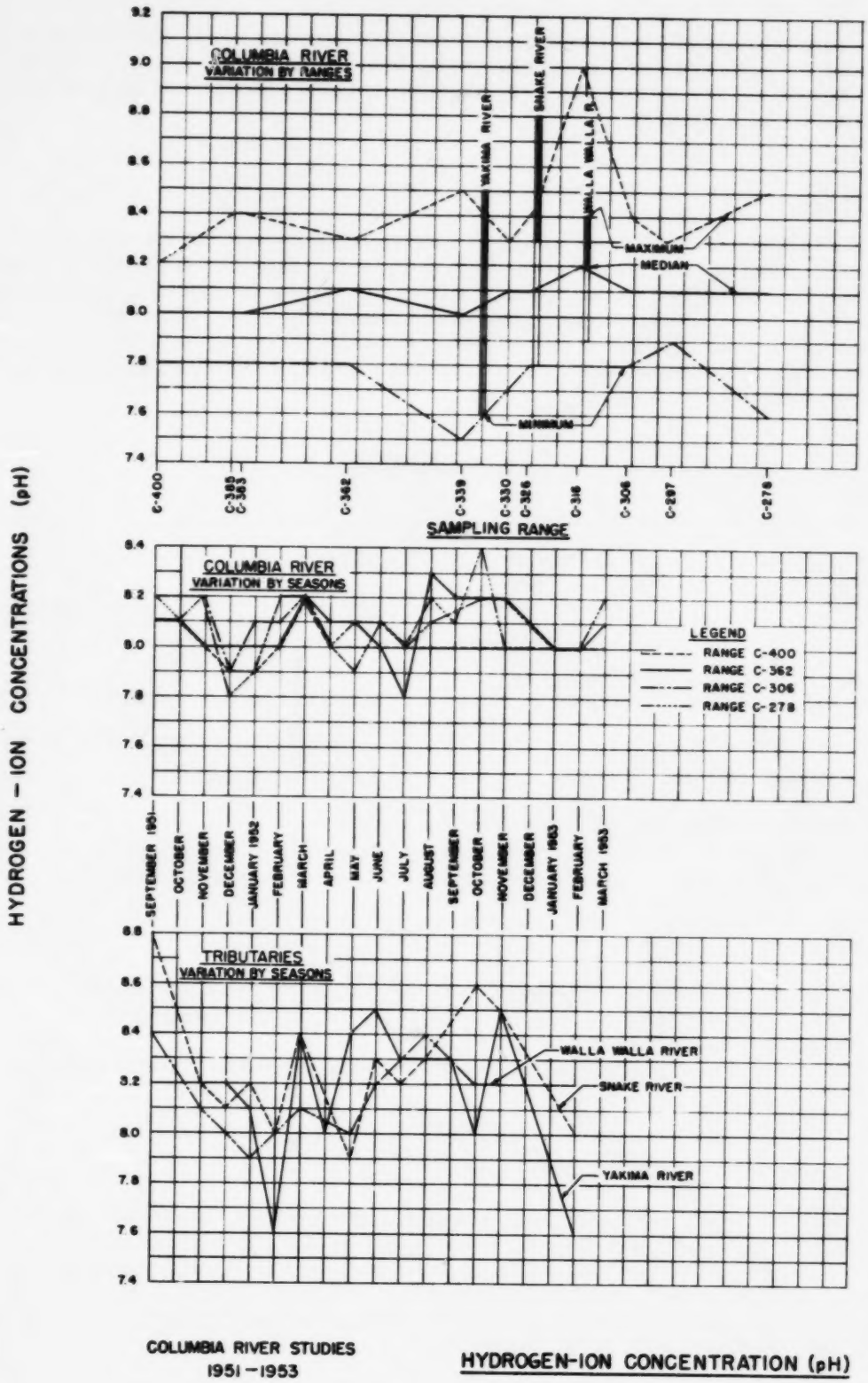

HYDROGEN - ION CONCENTRATIONS (pH)
COLUMBIA RIVER
VARIATION BY RANGES
YAKIMA RIVER
SNAKE RIVER
WALLA WALLA R.
MAXIMUM
MEDIAN
MINIMUM
C-400
C-385
C-383
C-362
C-339
C-330
C-326
C-316
C-306
C-297
C-278
SAMPLING RANGE
COLUMBIA RIVER
VARIATION BY SEASONS
LEGEND
RANGE C-400
RANGE C-362
RANGE C-306
RANGE C-278
SEPTEMBER 1951
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1952
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1953
FEBRUARY
MARCH 1953
TRIBUTARIES
VARIATION BY SEASONS
WALLA WALLA RIVER
SNAKE RIVER
YAKIMA RIVER
COLUMBIA RIVER STUDIES
1951 - 1953
HYDROGEN-ION CONCENTRATION (pH)

Figure 10

Alkalinity

Figure 11 presents the methyl orange alkalinity results. Values were somewhat greater in the Columbia River during periods of low flow. The influx of tributaries caused considerable increases in the downstream waters. Results varied from a minimum of 43 p.p.m. to a maximum of 170 p.p.m. below the Snake River. The maximum tributary result found was 310 p.p.m. in the Walla Walla River. The average value for the area above the Yakima River was 65 p.p.m. Phenolphthalein alkalinity, ranging from 0 to 30 p.p.m., was occasionally found in and below the tributaries.

Long-term Data

To assist in determining long-term effects of the radioactivity on chemical and physical characteristics, the results of river analyses made by the Atomic Energy Commission's prime contractors are presented in figure 12. The period covered is from mid-1944, when the plant was first placed in operation, to the latter part of the year 1950. Also shown on the same chart, for comparative purposes, are the data obtained by the Public Health Service group during the period of this study.

Data are given for ammonia nitrogen, temperature, dissolved oxygen, hydrogen-ion concentration (pH), methyl orange alkalinity, and total solids.

Based on the physical and chemical characteristics for which long-term results were available the data gathered by the two groups compare very favorably. The fluctuations can generally be attributed to seasonal factors.

Mineral Analyses

Data reaching back to mid-1950 were available from the General Electric Company on the mineral constituents in the water in the section of the river extending between Ranges C-385 and C-370. These values are presented in figure 13, along with limited additional data accumulated by the Public Health Service.

Where there are overlaps in results the agreement between laboratories is good. It is of interest to note that the results are in the range of magnitude reported by the U.S. Geological Survey for 1910-1911 (5).

Variations were created by the usual seasonal fluctuations and the influx of tributaries. During the period Feburary 1952 to April 1953 the concentrations of the mineral constituents in the Columbia River water, as shown by Public Health Service results, ranged from 17 to 24 p.p.m. for calcium, 4 to 6 p.p.m. for magnesium, 0.03 to 0.14 p.p.m. for iron, 0.00 to 0.08 p.p.m. for manganese, 0.003 to 0.04 p.p.m. for copper, 8 to 18 p.p.m. for sulfates, and 0.0 to 0.1 p.p.m. for phosphates. General Electric Company results for the same period varied from 1.3 to 2.2 p.p.m. for sodium, and 4 to 7 p.p.m. for silica. The values indicate conditions favorable for support of aquatic life during any season.

In general, the same pattern of variation took place in tributary waters

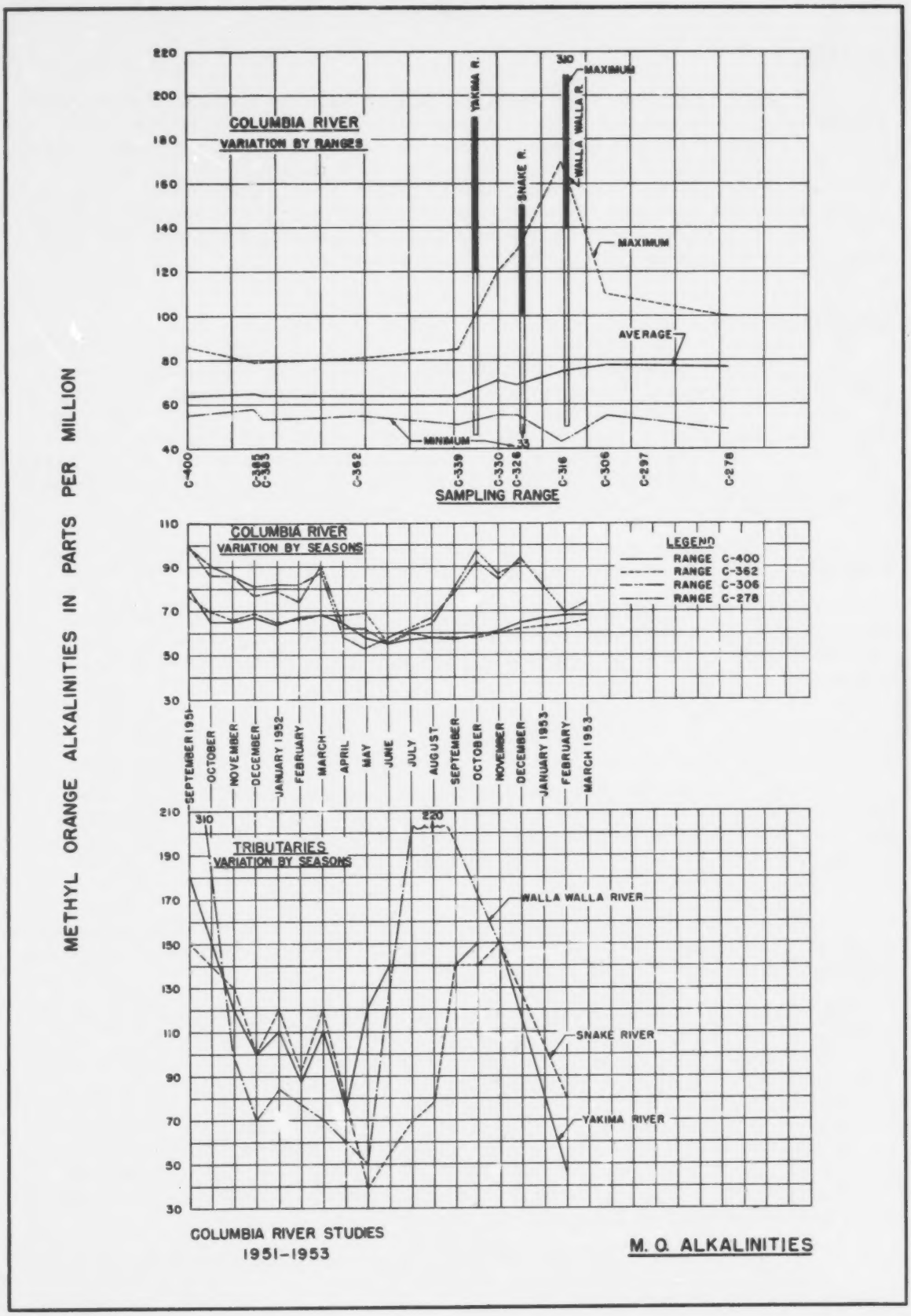
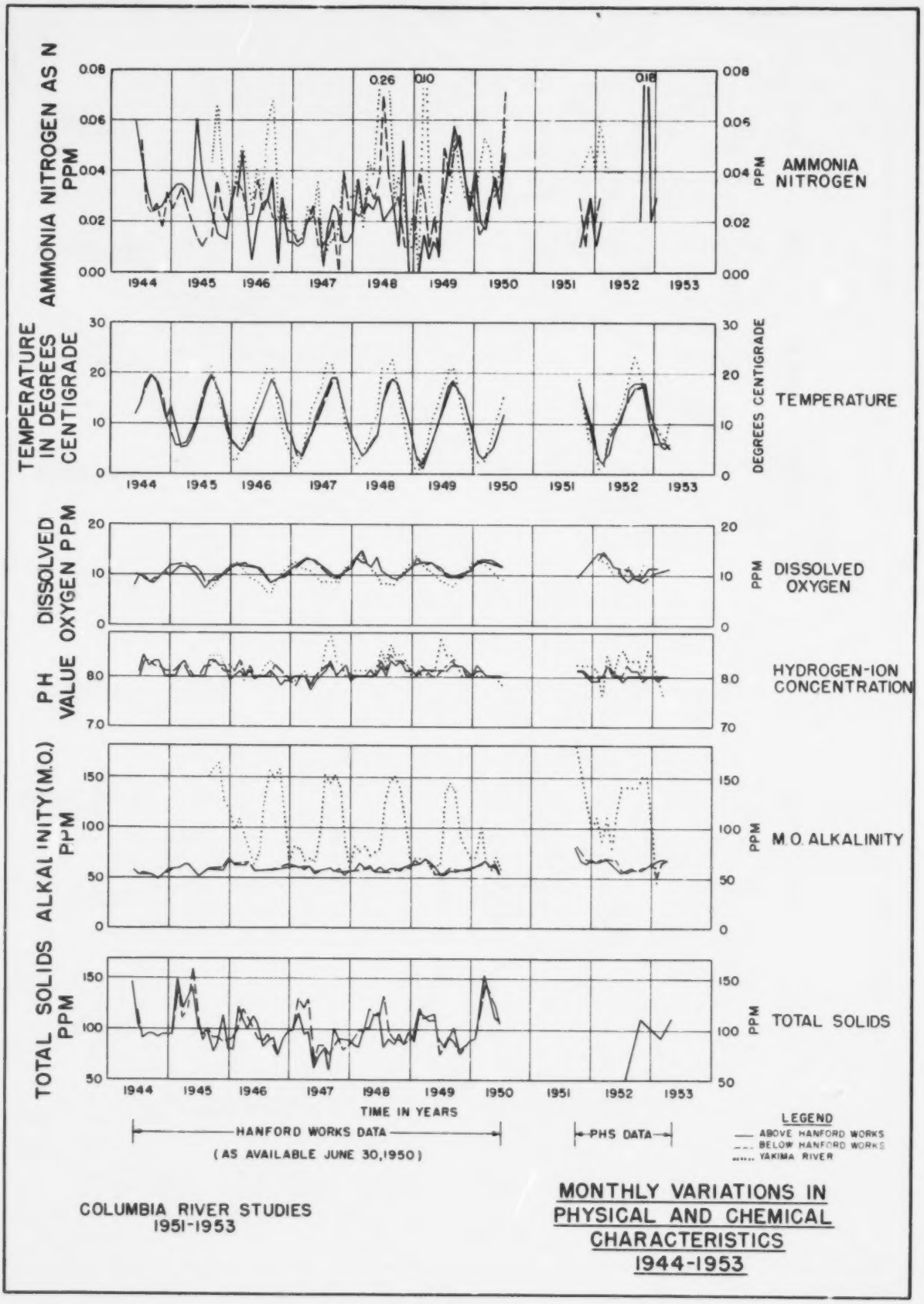

METHYL ORANGE ALKALINITIES IN PARTS PER MILLION
COLUMBIA RIVER
VARIATION BY RANGES
YAKIMA R.
SNAKE R.
WALLA WALLA R.
310
MAXIMUM
MAXIMUM
AVERAGE
MINIMUM
35
C-400
C-385
C-383
C-362
C-339
C-330
C-328
C-316
C-306
C-297
C-278
SAMPLING RANGE
COLUMBIA RIVER
VARIATION BY SEASONS
LEGEND
RANGE C-400
RANGE C-362
RANGE C-306
RANGE C-278
SEPTEMBER 1951
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1952
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1953
FEBRUARY
MARCH 1953
TRIBUTARIES
VARIATION BY SEASONS
310
220
WALLA WALLA RIVER
SNAKE RIVER
YAKIMA RIVER
COLUMBIA RIVER STUDIES
1951-1953
M. O. ALKALINITIES

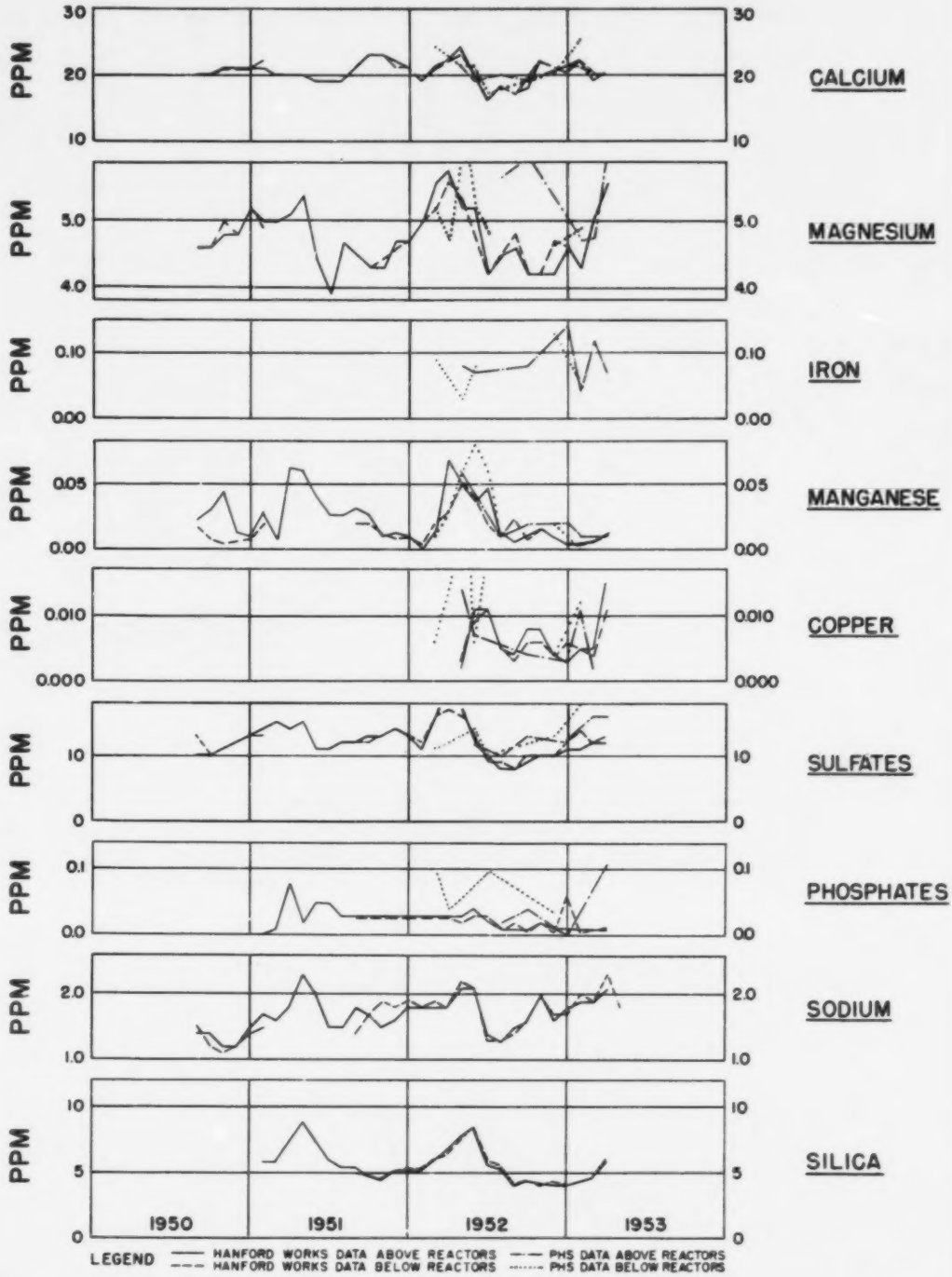
Figure II



COLUMBIA RIVER STUDIES
1951-1953

MONTHLY VARIATIONS IN PHYSICAL AND CHEMICAL CHARACTERISTICS 1944-1953

Figure 12



COLUMBIA RIVER STUDIES
1951-1953

MINERAL CONTENT
VARIATION BY SEASONS
1950-1953

Figure 13

but the extremes were more pronounced. Actually, such values as 0.48 p.p.m. for copper, 1.1 p.p.m. for iron, and 0.13 p.p.m. for zinc seem higher than warranted. There was neither an apparent source for such quantities nor was there an aquatic alteration that would normally accompany such concentrations. These high values did occur with very turbid samples and it is possible that this excess turbidity may have adversely influenced the results.

BACTERIOLOGICAL EXAMINATIONS

The results of the bacteriological examinations on individual water samples are presented in Appendix B. Maximum, median, and minimum values are shown in figure 14 to illustrate the variations at individual sampling points on each range.

Maximum values of 3,000 to 4,600 MPN per 100 ml. occur along the shore several miles below Pasco, Kennewick and the tributaries. There is a definite sewage load entering the Yakima River (4) but most of it enters far enough upstream so that the coliform values are usually reduced to under 1,000 per 100 ml. near the mouth. The effluent from the Richland Sewage Treatment Plant, discharging into the Yakima River near its mouth, receives secondary treatment and post-chlorination, and thus does not have any appreciable influence on the downstream coliform density. The Walla Walla River is a small turbid stream that is periodically either in flash flood stage or almost stagnant. Therefore it does not greatly influence the quality of Columbia River water, though samples from this tributary occasionally show a high MPN value.

Since the termination of these studies the cities of Kennewick and Pasco have begun operation of primary sewage treatment plants.

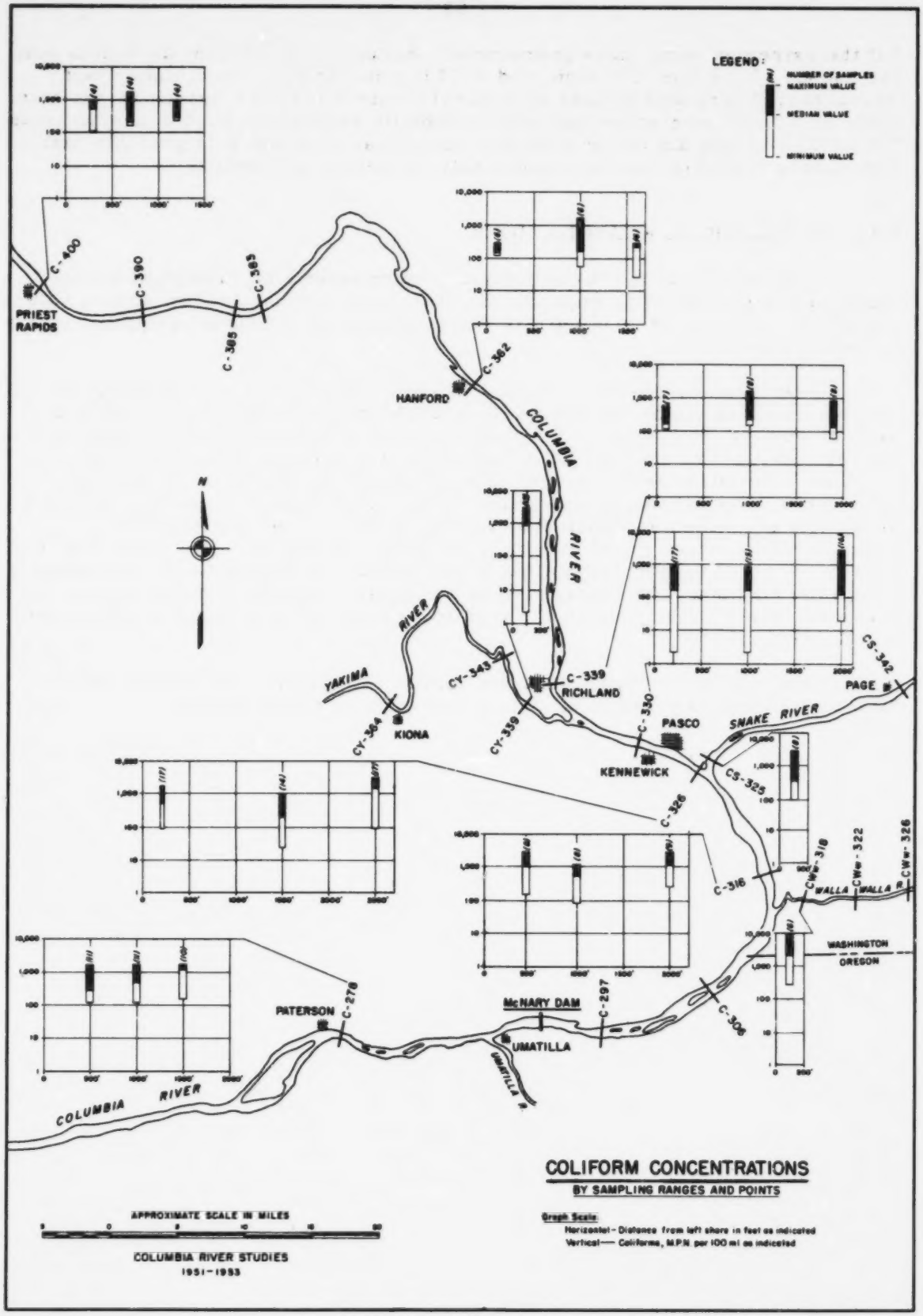

LEGEND:
NUMBER OF SAMPLES
MAXIMUM VALUE
MEDIAN VALUE
MINIMUM VALUE
PRIEST RAPIDS
C-400
C-390
C-385
C-365
HANFORD
C-362
COLUMBIA RIVER
YAKIMA RIVER
KIONA
CY-364
CY-343
CY-339
C-339
RICHLAND
C-330
PASCO
KENNEWICK
SNAKE RIVER
CS-342
PAGE
CS-325
C-326
C-316
CWw-318
CWw-322
CWw-326
WALLA WALLA R.
WASHINGTON
OREGON
C-308
C-297
McNARY DAM
UMATILLA
UMATILLA R.
C-278
PATERSON
COLUMBIA RIVER
N
APPROXIMATE SCALE IN MILES
COLUMBIA RIVER STUDIES
1951-1953
COLIFORM CONCENTRATIONS
BY SAMPLING RANGES AND POINTS
Graph Scale:
Horizontal - Distance from left shore in feet as indicated
Vertical — Coliforms, M.P.N. per 100 ml as indicated

Figure 14

CHAPTER VI

ECOLOGICAL STUDIES

Ecological studies were made to determine existing aquatic populations, the interrelationships between the various organisms and the conditions under which they occur. Aquatic populations may readily reflect a change in environmental conditions. Thus the information obtained can be used to detect any changes that may have occurred in the river and the possible reasons for these changes. It can also be used as a base in future studies to determine the effects of impoundments, irrigation, and domestic or industrial pollution.

SAMPLING AND LABORATORY METHODS

The overall program involved the collection of qualitative and/or quantitative samples of plankton, filamentous algae, bottom animals and fish at all ranges at bi-weekly or monthly intervals. Pertinent physical and chemical information was obtained at the time and place of the collection of these samples. Limited life-history studies were made on certain resident species of fish. The methods generally used in the collection of aquatic organisms were those given by Welch (6), with adaptations to fit local conditions.

Quantitative plankton samples were taken monthly at each range. River water was collected from the surface at from ten to twenty points across the range and composited to give a 5-gallon sample. Two-liter portions were concentrated in a Foerst centrifuge and the total count of organisms determined in a Sedgwick-Rafter counting cell. The principal organisms were identified to genera and reported as number per milliliter. Ten-liter portions were concentrated in the centrifuge, dried at 60°C. for 24 hours and weighed, the results being reported as wet weight in milligrams per liter. The samples were then ashed in a muffle furnace for 30 minutes at 600°C. and reweighed to determine the content of organic matter, also reported in milligrams per liter.

Quantitative bottom animal samples were taken in shallow riffle areas at monthly intervals insofar as possible. As aquatic animals vary greatly in different habitats, a special effort was made to take the samples in similar habitats at all ranges. Three 1-square foot samples were taken at each location with a Surber sampler, in water generally 1 to 1-1/2 feet deep. These were composited, preserved in 10 per cent formalin and taken to the laboratory. The animals were manually sorted from the debris and separated into groups, generally to order only, since the General Electric Company laboratories were making and are continuing to make more specific identifications. They were then counted and weighed after blotting for 1 minute to remove surface moisture. Bottom animals were reported as number per square foot and the wet weights given in grams per square foot. High water precluded the collection of samples in the Columbia and Snake Rivers during April, May, June and July of 1952, although a few collections were made in the Yakima and Walla Walla Rivers during that period.

In this report juvenile fish include small fish, generally weighing less than 10 grams and mostly young-of-the-year, but including adults of small species such as dace or sticklebacks. Adult fish generally include fish weighing over 10 grams and in most cases sexually mature, but may include the young of some large-sized species.

Juvenile fish samples were taken once or twice each month at all ranges. Collections were made by seining in areas of fish concentration, with 6-, 10-, or 20-foot, 1/4-inch mesh, minnow seines. The relative abundance of the various species was noted.

Adult fish collections were limited principally to Range C-362, in the vicinity of Hanford. Collections were made bi-weekly or monthly with gill nets. Bottom sets were made overnight with 1-inch, 2-inch, and 3-inch mesh (square) nets from 75 to 375 feet long. A few fish were collected at Hanford and other ranges with sport fishing gear. The total length, weight, sex and species of each specimen was noted.

Summaries of the ecological data covering the period September 1951 to March 1953 inclusive are presented graphically. Seasonal changes as well as fluctuations between ranges are also presented where significant.

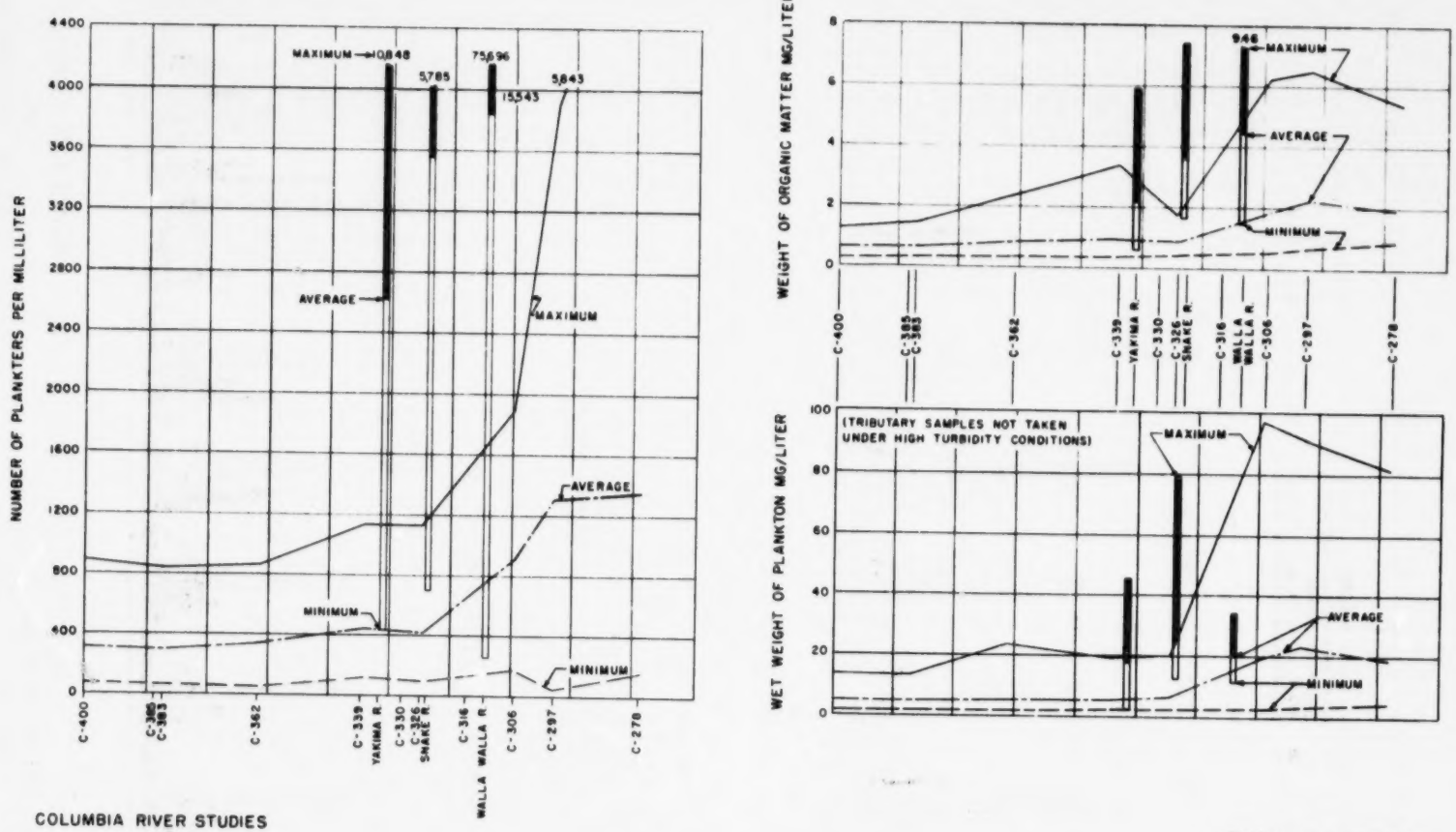
PHYSICAL AND CHEMICAL CONDITIONS

Physical and chemical conditions, as reported previously, are well within limits expected to support a good mixed aquatic biota at all ranges (7). The major changes in these conditions were mainly due either to seasonal fluctuations or to the influx of tributaries. While these changes appeared to definitely affect plankton populations there was no major effect on bottom animals or fish. Average values in many instances are not significant, due to large seasonal variations, but since such values are based on similar samples they are useful for comparisons between ranges. The effect on aquatic populations depends more on maximum or minimum values of certain characteristics such as temperature, dissolved oxygen, pH, and concentrations of toxic materials, than on the average values of these same characteristics or materials.

PLANKTON

The total numbers of plankters, as well as the total wet and organic weight of plankton, are shown in figure 15 on the basis of sampling locations. A further breakdown, showing the kinds of organisms present and their seasonal variation, is given in figure 16. Data on individual samples are tabulated in Appendix B.

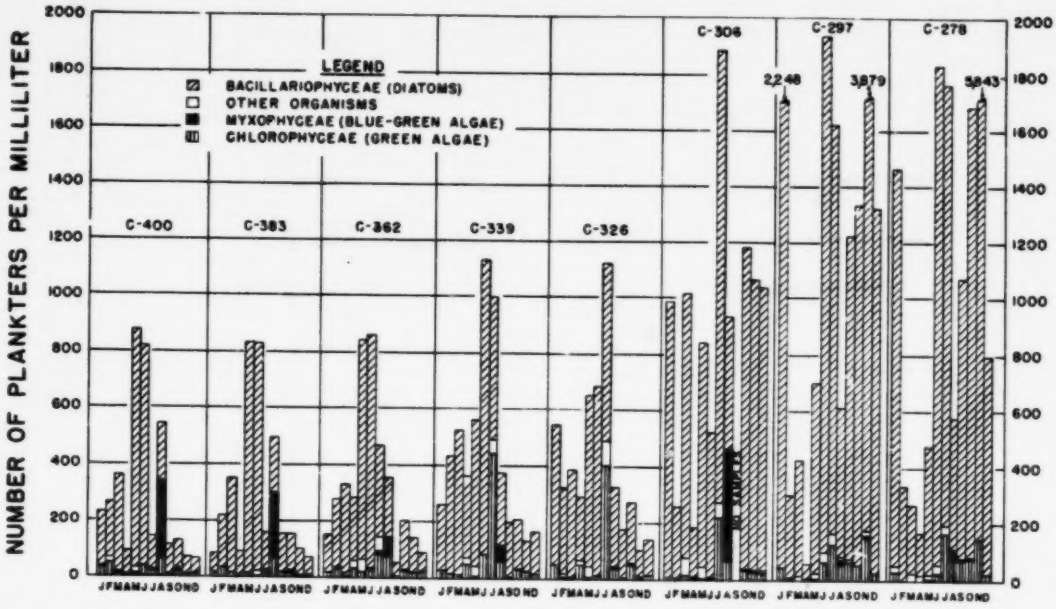
The plankton in the Columbia River are predominantly diatoms, the principal genera present consisting of Asterionella sp., Cyclotella sp., Fragilaria sp., Melosira sp., Navicula sp., and Synedra sp. Asterionella sp. and Cyclotella sp. appear in definite pulses and cause a large seasonal variation in the number of organisms. The pulse of Asterionella sp., as evidenced in figure 17, appears principally during peak water conditio in May and June, but is practically absent during the remainder of the year. This would indicate that the organism builds up to a large extent in reservoirs and sloughs and is released when these areas are flushed out by high water. Studies in Roosevelt Lake, presented in Appendix C, substantiate this. Large numbers of these organisms were found in the lower reservoir in April, but did not show up in great numbers in the main river until large flows were discharging from the reservoir. During the previous fall the phytoplankton population had been very sparse in Roosevelt Lake.

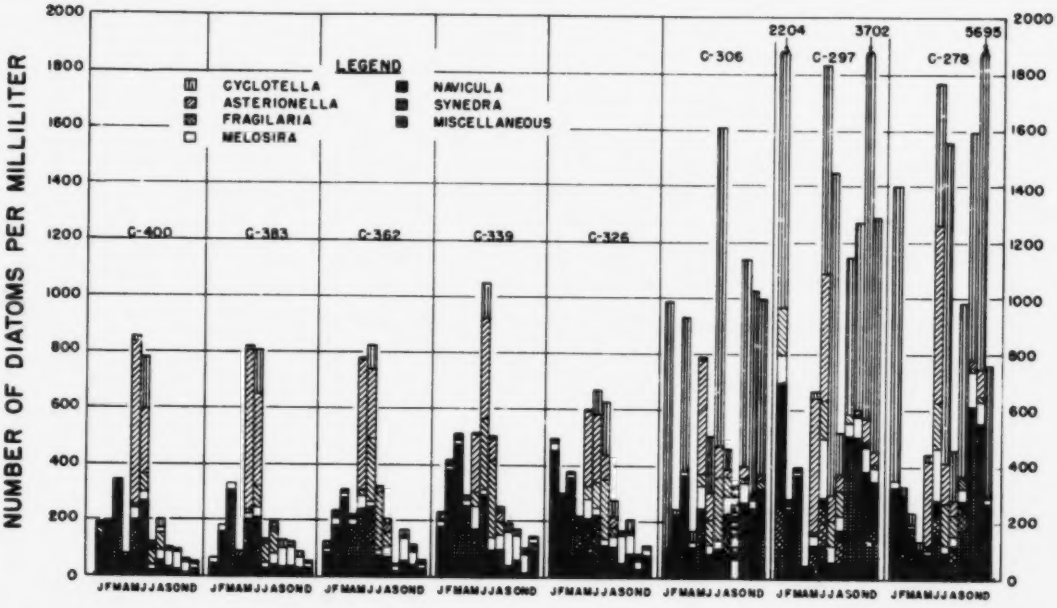


COLUMBIA RIVER STUDIES
1951-1953

TOTAL PLANKTON
NUMBER OF PLANKTERS
AND
WET AND ORGANIC WEIGHT

Figure 15





COLUMBIA RIVER STUDIES
1951-1953

NUMBER OF PLANKTERS
BY
GENERIC COMPOSITION

Figure 16

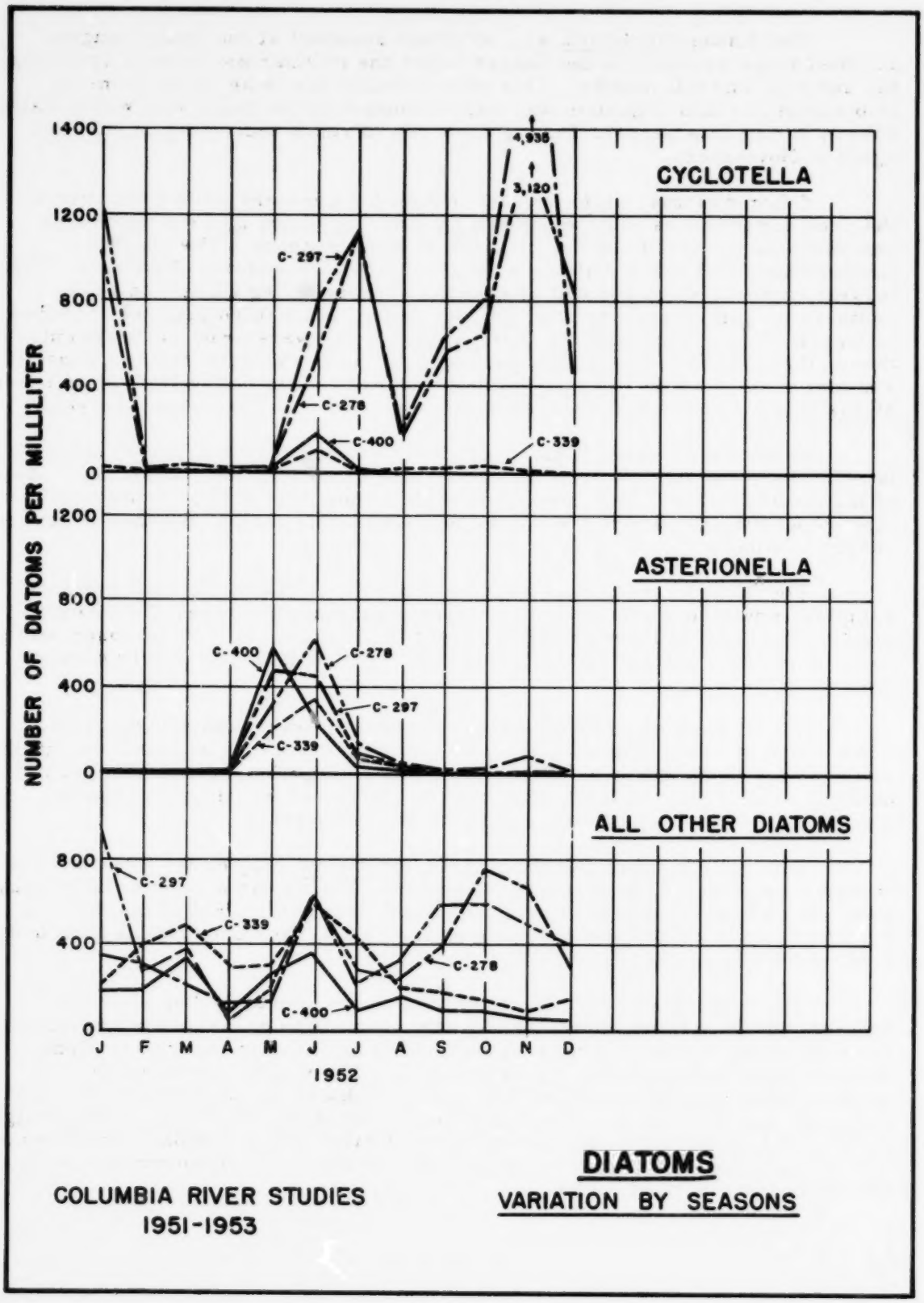

CYCLOTELLA
ASTERIONELLA
ALL OTHER DIATOMS
NUMBER OF DIATOMS PER MILLILITER
1400
1200
800
400
0
4,938
3,120
C-297
C-278
C-400
C-339
J F M A M J J A S O N D
1952
COLUMBIA RIVER STUDIES
1951-1953
DIATOMS
VARIATION BY SEASONS

Figure 17

The diatom Cyclotella sp., while not abundant at the upper ranges, reached large numbers in the ranges below the tributaries, especially during the summer and fall months. This was probably due to an influx from the tributaries, as this organism was quite abundant in the Snake and Walla Walla Rivers during this period. Pulses appeared to reach their peak in July and again in November.

Other diatoms, while present in smaller numbers when compared to the peak occurrences of Asterionella sp. and Cyclotella sp., did make up a considerable proportion of the plankton at some seasons. The seasonal fluctuations of all other diatoms as a group are also shown in figure 17. The largest numbers were present at seasons corresponding closely to peak numbers of Asterionella sp. and Cyclotella sp., but a third peak was reached in March when Asterionella sp. and Cyclotella sp. were practically absent. Of these other diatoms, Fragilaria sp. appeared most abundant during the hot summer months while Navicula sp. was most abundant during the winter season. Melosira sp. appeared in reasonably uniform numbers throughout the year.

Green algal forms (Chlorophyceae) were present in greatest numbers in late summer and fall but even then accounted for only a very small percentage of the total plankton. Blue green forms (Myxophyceae) did not appear uniformly throughout the year and for no apparent reason were fairly abundant at several ranges in August.

Zooplankton organisms were very sparse in the main river but most samples contained a small number of protozoans and rotifers. Crustaceans, mostly copepods, while practically absent in the main river were observed to build up to some extent in slough areas, especially during the early summer months.

There were no obvious changes in numbers of plankton organisms, from range to range, that could not be attributed to either seasonal variation or the influx of tributaries. While there was a large increase in numbers of diatoms at the lower ranges, this could be attributed mostly to one diatom, Cyclotella sp., from the Snake and Walla Walla Rivers.

It is possible that blooms of Asterionella sp. may cause some trouble in water supplies. This organism when concentrated had a very definite fishy odor. It was reported that at least one water treatment plant in the State of Washington was having some trouble with clogged filter beds, which may have been caused by an abundance of this organism.

The weights reported for plankton are not considered an accurate measure of the plankton itself. It was not possible to separate the organisms from all of the silt and extraneous material suspended in the water. Hence these weights include some of this material. The weight, consequently, is much greater during periods of high turbidity due to the presence of foreign material, and does not correspond directly with plankton counts. These weights were used principally in comparing samples taken under similar conditions at the various ranges and for computing total radioactivity of the materials in suspension in the river water.

BOTTOM ANIMALS

Some difficulty was encountered in sampling for bottom animals. Due to the large seasonal fluctuations in water levels, very fast current and hard rocky bottom, uniform samples could not be taken at all seasons of the year. Bottom sampling was thus confined to shallow riffle areas and low water conditions. Even then, the variation in individual samples was very large. Samples taken at low water stages in late 1951 and early 1952 were expected to represent average conditions. However, an extreme low water stage several feet below the minimum of 1951 and early 1952 was reached in late 1952. Samples taken at some of the ranges then indicated bottom animals to be in much greater abundance than previously found. It is believed, however, that an average of all the samples taken would represent a normal condition. A sudden rise in river levels in mid-January 1953 precluded the collection of further samples.

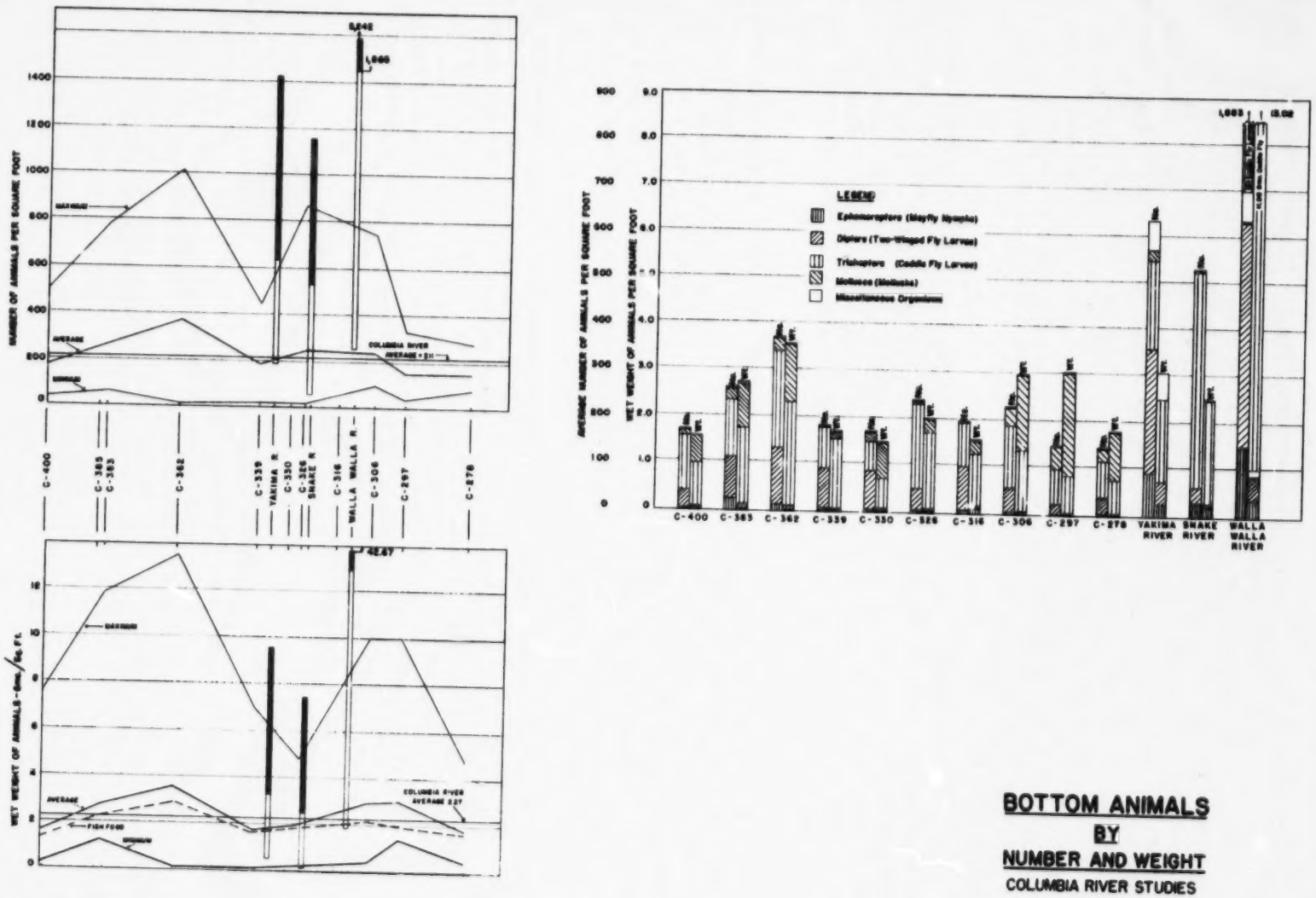
Figure 18 portrays the information obtained on bottom animals during the period August 1951 to December 1953, inclusive. The results for individual samples are given in Appendix B. As the number and weight of these organisms varies widely in different habitats or even in different parts of the same habitat, and since this variation is usually as great as or greater than the seasonal variation, no effort is made to graphically portray the seasonal variation.

The average values for the number, weight and kinds of animals present are the criteria upon which any conclusions should be based. In addition, riffle areas are generally considered the most productive part of a stream and the number and weight of animals found there would probably be greater than for the stream as a whole. As the Columbia River has a very fast current and most of the bottom area is quite rocky, the major portions would be expected to be quite productive. The few areas with deep water and sand bottom would, however, probably be less productive.

In order to compare the productivity of some of the deeper areas with that of riffle areas where samples were taken, a number of ordinary concrete building blocks, measuring 4" x 8" x 16", were distributed at various depths on the river bed. Floats were tied to these blocks in order to locate and remove them. The blocks were removed after being in place for from 3 to 6 months. The organisms were washed off and counted and compared to those removed at the same time from blocks in riffle areas. By comparison it was found that organisms in areas from 10 to 15 feet deep were approximately one-half as abundant as those in shallow riffle areas.

The kinds of organisms present are generally considered clean water forms and few if any definite pollutional types were found at any of the various sampling locations. On the basis of numbers the most predominant forms were midgefly and caddisfly larvae. Caddisfly larvae and mollusks predominated on a weight basis. Mayfly nymphs were present to some degree at all ranges. The only difference that could be noted between ranges was the possibly greater numbers of mayfly nymphs in the upper ranges and the greater number and weight of mollusks in the more turbid and alkaline waters below the tributaries.

The results presented on bottom animals exclude crayfish. While these



BOTTOM ANIMALS
BY
NUMBER AND WEIGHT
COLUMBIA RIVER STUDIES
1951-1953

Figure 18

were fairly abundant at all ranges, quantitative samples were collected too infrequently to permit the use of such data for purposes of comparison. In computing average values for fish food only one-half of the weight of mollusks was used, as these organisms were weighed in the shell and the entire weight could not be considered to be utilized for food.

Based on food grade (8) this river would be considered average to rich in fish food organsims at all ranges. While individual samples show considerable variation between ranges, the average values for number and weight of bottom animals are comparable at all ranges and show no marked changes. No detrimental effect on these animals is indicated anywhere within the study area.

FISH

Most of the species of fish that are known to exist in the Columbia River were collected or observed during this study. This includes species from Roosevelt Lake (Appendix C) and Bonneville Reservoir (Appendix D) as well as those obtained from brackish water near the mouth of the river. These fish will be referred to by their common names in the discussion below. The following species have been identified (9) (10) (11):

Petromyzonidae-Lampreys

Pacific lamprey - Entosphenus tridentatus

Acipenseridae-Sturgeons

White sturgeon - Acipenser transmontanus

Clupeidae-Herrings

American shad - Alosa sapidissima

Salmonidae-Salmon and Trout

Chinook or King Salmon - Oncorhynchus tshawytscha

Silver Salmon - Oncorhynchus kisutch

Blueback or Red Salmon - Oncorhynchus nerka nerka

Kokanee Salmon - Oncorhynchus nerka kennerlyi

Cut throat trout - Salmo clarkii

Brown trout - Salmo trutta

Steelhead or Rainbow trout - Salmo gairdnerii

Dolly Varden trout - Salvelinus malma spectabilis

Coregonidae-Whitefishes

Mountain Whitefish - Prosopium williamsoni

Lake Whitefish - Coregonus clupeaformis

Osmeridae-Smelts

Eulachon or Smelt - Thaleichthys pacificus

Catostomidae-Suckers

Mountain Sucker - Pantosteus jordani

Fine-scaled Sucker - Catostomus syncheilus

Coarse-scaled Sucker - Catostomus macrocheilus

Cyprinidae-Minnows, Dace, and Chubs

Carp - Cyprinus carpio

Tench - Tinca tinca

Chiselmouth - Acrocheilus alutaceus

Columbia River Chub - Mylocheilus caurinus

Dace - Rhinichthys umatilla

Dace - Rhinichthys falcata

Spreckled Dace - Rhinichthys oscula carringtoni

Long-nosed Dace - Rhinichthys cataractae dulcis

Columbia Squawfish - Ptychocheilus oregonensis

Redside Shiner - Richardsonius balteatus balteatus

Ameiuridae-Catfishes

Brown bullhead - Ameiurus nebulosus

Gadidae-Cods

Pacific Tomcod - Microgadus proximus

Burbot or Ling - Lota lota

Pleuronectidae-Halibuts and Flounders

Starry Flounder - Platichthys stellatus

Gasterosteidae-Sticklebacks

Three-spined Stickleback - Gasterosteus aculeatus

Percidae-Perch

Yellow Perch - Perca flavescens

Centrarchidae-Black Basses and Sunfishes

Bluegill - Lepomis macrochirus

Pumpkinseed - Lepomis gibbosus

White crappie - Pomixis annularis

Black crappie - Pomoxis nigro-maculatus

Smallmouth Black Bass - Micropterus dolomieu

Largemouth Black Bass - Micropterus salmoides

Cottidae-Sculpins

Sculpin - Cottus beldingii

Sculpin - Cottus asper

Sculpin - Cottus rhotheus

Smooth Sculpin - Leptocottus armatus

There are no doubt other species of fish present in the Columbia River. Some which have been reported by others are the Kamloops rainbow trout (Salmo gairdnerii kamloops), several additional species of salmon, and the trout perch (Columbia transmontana). Other species of minnows and sculpins have also been recorded. Many of the species collected are not native to the Columbia River system but have been introduced from other areas.

No data on quantitative estimation of fish populations are presented in this report, although records were kept on relative abundance of species in each collection, as shown in Appendix B. The methods used, seining and gill netting, would be considered selective and would not present an accurate measure of fish populations. The information could, however, be used for a comparison between ranges.

In the juvenile fish collections shiners and squawfish were the predominant species at all ranges and at all seasons of the year in the Priest Rapids-Paterson section. Chiselmouth, chubs and suckers were also fairly abundant. Dace and sculpins were generally present, particularly in riffle areas, but in fewer numbers. Other species tend to show a seasonal variation. Chinook salmon, while very abundant during March, April and May, were practically absent for the remainder of the year. Bass and sunfish appeared to be most abundant in the fall but were occasionally collected at other seasons. Other species, such as sticklebacks, carp and crappie, were found in occasional collections. There were no major differences in the juvenile fish collections from the different ranges. Juvenile salmon, when present, were more frequently caught in the upper ranges while spiny-rayed species seemed more abundant below. Small mouth bass were more numerous in the Yakima River but other species found in the tributaries were similar to those in the main river. In general, juvenile fish and minnows were quite abundant at all ranges.

The only extensive collections of adult fish were made with gill nets at Range C-362. A summary is given in Appendix B. Suckers, squawfish and bass were most predominant in these catches. A few blueback salmon were taken in early summer during their period of heavy migration through this area.

Observations, sport fishing, counts of migratory species over Bonneville Dam by the Corps of Engineers (12) and reports from the General Electric Company (13) (14) and the U.S. Fish and Wildlife Service (15) (16) support the following comments on fish in the Columbia River.

Fairly large numbers of chinook salmon spawn within the Hanford Works Reservation and larger numbers of both chinook and blueback salmon pass through this area to spawning grounds upstream. It has been reported that more than 80 per cent of the Columbia River race of blueback salmon spawn in tributaries upstream from the Hanford Works. Adult salmon do not feed while in this area to spawn but the fingerling fish must sustain themselves on their way downstream to salt water. The time the juveniles spend in this section is evidently fairly short, as collections show juvenile salmon present in significant numbers only during the spring months. Salmon help support an extensive commercial and sports fishery near the mouth of the Columbia River and in offshore waters. There is, however, no commercial fishing in the Priest Rapids - Paterson area. A few chinook salmon are caught by sport fishermen and some are taken by Indians as they move upstream to spawn. Counts over Bonneville Dam have shown these species to be somewhat on the increase in the last few years. Record runs of blueback and chinook salmon were recorded in 1952 and 1953.

Steelhead are probably next to salmon in importance. These migratory fish, weighing generally from 5 to 20 pounds, support a fairly extensive sport fishery above McNary Dam as well as in other parts of the Columbia River and tributaries and to some extent a commercial fishery in the lower river. It is believed that their feeding is quite limited during the summer and early fall months in the study area. Of a number of stomachs examined few were noted which contained any food material. Later, however, a few specimens taken had full stomachs, principally caddisfly larvae. Evidence indicates that these fish spawn mainly in tributary streams. Their offspring must pass through the main study section, but it is believed that very few of the juveniles are taken on their way downstream. Record runs of steelhead were reported passing over Bonneville Dam in 1952.

The whitefish is a semi-migratory species taken in fairly large numbers by sport fishermen in the Priest Rapids - Paterson section of the Columbia River and the tributaries. Most of the catches are made in the late fall and winter when they appear in fairly heavy concentrations in certain areas, probably for spawning purposes. Numerous ripe and spent females have been taken in riffle areas between November and February although no juveniles have been collected. These fish are actively feeding, mostly on caddisfly and midgefly larvae and snails, even during the winter months. It is believed that they remain in deep water areas during the summer months and may move for some distance to desirable spawning riffles late in the season. It is not felt, however, that they move great distances, as do the truly migratory species. Counts over Bonneville Dam have been small as compared with numbers found in some upstream areas of the river.

Smallmouth and largemouth bass occur in fair numbers, especially near slough areas and in the tributaries. During the spring months, before high water conditions occur and while the sloughs are warming up, these fish congregate in the slough areas and furnish a fair amount of sport fishing. Later they move from the sloughs into the main river. Some successful spawning occurs in the Priest Rapids - Paterson section, usually in July and August.

Some fish may spawn earlier in the slough areas if not disturbed by the influx of colder water during the high flow period. Nests containing eggs were observed as early as the latter part of April 1952 in the vicinity of Hanford and McNary Dam, but were not successfully hatched. The spring runoff brought an influx of considerably colder water which caused the adult bass to abandon their nests. Successful hatching has been observed, however, in July and early August. Fry have been observed rising from the nests and juveniles of various sizes have been collected following this period. It is believed that a large part of the spawning potential is lost due to the large fluctuations in flow during the spawning season. Bass have gained considerable favor among sport fishermen in this area and are expected to be among the most important species from the standpoint of sport fishing in the McNary reservoir. The decrease in water level fluctuations due to this impoundment should favor successful spawning, and other conditions are expected to be favorable for an increase in this species.

Age and growth studies were made on 225 adult smallmouth bass collected in the Hanford-Richland area. It was determined that very favorable growth was made in this area when compared to this species in streams in other sections of the country (17). Tagging studies conducted in cooperation with the Richland Rod & Gun Club and the General Electric Company (18) showed that some individuals may move as much as 50 miles to favorable sloughs or spawning areas.

Sturgeon is another resident species that is favored by fishermen. Many are reported caught in the lower Snake River as well as in many areas in the Columbia. These fish have been reported to reach weights of 1,200 pounds but most of those taken are from 10 to 100 pounds. It is not expected that the McNary impoundment will have any adverse effects on this species but from observations in Bonneville Reservoir, where there now exists a limited commercial fishery for sturgeon, it appears that an impoundment may favor an increase.

By far the greatest part of the resident fish population in this area is made up of undesirable species such as squawfish, suckers and carp. The young of these serve to some extent as food for more desirable species, but a disproportionate amount of the river productivity is used by the undesirables. It is expected that conditions within the McNary impoundment may favor further the increase of undesirables, but the expected increase in game fish may tend to offset this. Forage species such as chubs, shiners, dace and sculpins are quite abundant throughout the Priest Rapids - Paterson section. It is believed that these populations are sufficiently extensive to support far larger populations of game fish than now occur.

CHAPTER VII

RADIOLOGICAL STUDIES

The manufacture of fissionable materials, the increasing peacetime uses for atomic energy products, and the projected development of atomic power facilities introduce new problems in the field of environmental sanitation. One of these problems, of direct concern to many state and local health departments as well as to other public and private organizations, is the possibility of contamination of surface streams.

The radiological studies were undertaken to acquire a knowledge of the possible effects of radioactive effluents on the physical, chemical, and biological characteristics of surface waters, along with the rates of recovery from these effects. This also provided an opportunity for a variety of scientists to acquire competency in the techniques necessary to define a field problem involving radioactivity in a surface water.

SOURCES AND NATURE OF RADIOACTIVE MATERIALS

The major portion of radioactive materials entering the Columbia River are composed of beta particle emitters having relatively short half-lives. These are formed by the neutron bombardment of dissolved and suspended materials that are present in the water used as a coolant for the nuclear reactors.

Cooling water is pumped from the Columbia River into a complete water treatment plant. Treatment essentially includes coagulation, settling, filtration, and chlorination, with minor modifications being made from time to time.

After passing through the reactor the cooling water contains many short half-lived radioisotopes. Consequently, this effluent is held in open retention tanks for a short period in order to reduce the activity prior to discharge into the river. These effluents are monitored routinely by the General Electric Company and the total activity reported as "gross beta activity density", since there are seldom any alpha particle emitters in the coolant.

There are other sources of radioisotopes but these are considered to be minor. Some radioactive iodine (I^{131}) is discharged from the waste treatment unit of the experimental animal farm. Emergency spills can be diverted into standby retention tanks and later discharged into the ground through cribs near the river. Other wastes are also discharged into the ground, but reports of the General Electric Company and the U.S. Geological Survey indicate no measurable influence on the amount of radioactive materials now entering the Columbia River.

Because of the nature of the wastes the major radiological aspects of this project fall, roughly, into two categories: (a) the measurement of gross beta activity density of river water, aquatic organisms, and bottom muds, and (b) the identifications of these beta emitters by radiochemical analyses.

FIELD AND LABORATORY PROCEDURES

The methods for collecting samples for measurement of radioactive materials were largely those previously established for collection of samples for other analyses. For the preparation and actual counting, however, new techniques were developed or old ones adapted from other sources. Assistance was received primarily from the Sanitary Engineering Center at Cincinnati, Ohio, and the General Electric Company at Richland, Washington. Detailed methods and procedures, briefly discussed below, are given in Appendix A.

Water

Because of the relatively great width of the Columbia River and the "point" discharge of the pile cooling water effluent it was necessary to collect water samples repeatedly at 3 to 5 points at each cross-section to determine the degree of horizontal mixing occurring in the stream. Results indicated little or no vertical stratification at the down-stream ranges. Therefore, most of the samples were taken at 4-foot depths. Collections were made once per week at all important points.

The sample size was determined by the expected magnitude of the radioactivity and total solids in the water. Generally, the activity density in the Hanford Works Area was such that a 500-ml. portion was adequate. In other river locations it was necessary to use at least 1,000-ml. portions for reliable results.

All water samples were prepared for radiological beta counting by evaporating them to dryness in such a manner that the final moisture-free residue would be evenly plated on a 1-inch stainless steel dish.

For determination of the alpha particle emitters (uranium and plutonium) it was necessary to put this residue through an ether extraction so as to reduce the amount of absorbing material. On some occasions the count was obtained on small, clear water samples without an extraction from the residue.

Aquatic Organisms

Aquatic organisms on which radioactivity determinations were made included plankton, filamentous algae, bottom animals, juvenile fish, and adult fish. Specimens of each of these were obtained bi-weekly or monthly at all ranges.

Plankton

Plankton samples were collected by towing a standard, number 20 silk bolting cloth net across a range for approximately 15 minutes. The plankton concentrate was then removed from the net and preserved. Normally 0.2 to 0.5 gram was needed for an adequate sample. The centrifuge method generally employed for quantitative plankton determinations could not be used for obtaining these samples. Too much time was required to run the large volume of water necessary to obtain an adequate amount through the small capacity centrifuge normally used for quantitative samples. It might, however, be

possible to employ this method if a very large centrifuge were used.

During the earlier part of the study the plankton samples, after filtering and drying, were weighed into 50-ml. beakers for digesting and ashing. This was done principally to reduce the volume of material plated and thus reduce the self-absorption factor. After a number of parallel samples, for comparison between methods, it was decided that direct plating was most satisfactory because:

1. Most of the plankton consisted of diatoms, with the shells remaining intact. Thus the weight and volume of material was reduced only very slightly through digestion.

2. The plankton could be spread on the plate just as smoothly by direct plating as by digesting.

3. Direct plating minimized the possible loss of volatile isotopes.

4. Samples were prepared and counted in less time, thus reducing the large decay factor due to short half-lived isotopes in plankton.

Filamentous Algae

Field collections of algae were made by scraping from rocks, logs and other objects in the streams. Specimens were identified, usually to genera, and prepared for counting. Duplicate portions, weighing about 2 grams, were prepared for radioactivity counting by washing, blotting, weighing, digesting, ashing and plating.

Bottom Animals

Samples of bottom animals, collected by handpicking from rocks, logs, and vegetation, were separated from any debris, sorted into groups and identified to order. Duplicate portions of each group, weighing between 1 and 2 grams per portion, were prepared for counting by blotting, digesting, ashing, and plating.

Juvenile Fish

Collections of juvenile fish, usually taken with seines and nets, were sorted to species, identified, and arranged in size groups for radioactivity determinations. Three portions, containing one or more fish from each size group of each species, were used whenever possible. Each portion was usually made up of from 1 to 6 whole individuals of the same species. Portions weighing about 2 grams were generally used, a single fish being prepared when the individual weight was between 2 and 10 grams. Fish weighing over 10 grams were considered as adults for radioactivity counting purposes.

Each individual specimen within a sample was measured, blotted free of moisture, and placed in a tared 50-ml. beaker. The sample was then weighed and prepared for counting by digesting and evaporating according to the procedure used for bottom animals.

Adult Fish

For adult fish radioactivity determinations were confined to certain parts and organs. Where available, three individuals of a species were used from each collection. After identification and measurement of total length and weight of each fish, 1- to 5-gram samples of scales, muscle, liver, bone, ovary or testes, kidney, stomach contents, or skin were placed in tared 50-ml. beakers and weighed. The samples were then prepared for counting by the same procedure as that used for bottom animals.

Mud Samples

Mud sampling was extremely limited since there is very little such material in this swift, rocky-bottomed stream. Mud could be found in a few backwater areas, particularly in the tributaries, but in nearly all cases the sample was limited to the near shore area. Even then the sample would consist mainly of sand or gravel.

Samples were collected in a 1-liter, wide-mouthed, glass bottle by simply scooping up soil where the river was 1 to 2 feet deep and in such quantity as to give at least 20 grams of dry sample.

After draining off the excess water, a representative portion of the soil was oven dried, weighed, digested with nitric acid and heat, plated on a 1-inch stainless steel plate, ashed and reweighed before counting. After a count for beta particle emitters had been made, the sample was put through an ether extraction to remove the alpha particle emitters (Pu + U) from the excessive residue. The extracted material was then plated on a 1-1/2-inch stainless steel plate and counted for alpha activity.

Radiochemical Group Separations

In an effort to identify the various beta particle emitters found in water and aquatic organisms, radiochemical analyses (chemical cation group separations) were made on samples of Columbia River water, plankton, filamentous algae, caddisfly larvae, and fish. Samples were collected in the routine manner previously discussed, but it was usually necessary to obtain much larger portions. For example, 4 to 5 liters of water were necessary instead of the usual 0.5 liter. The chemical work involved a separation into soluble and insoluble portions, and then further separation of the soluble portion into 8 elements or groups of elements, by use of the chemical "carrier" technique.

The grouping of the various elements was determined somewhat by the information available regarding the chemical composition of the water; type of reactors used; selectivity of biological organisms in the uptake of minerals; analyses of gross decay curves; and available radiochemical studies of pile cooling water effluents prior to discharge into the river (19). The groups separated from the soluble portion were:

1. Copper
2. Arsenic
3. Phosphorus
4. Rare Earths
5. Iron and Chromium
6. Zinc and Manganese
7. Calcium, Strontium, and Barium
8. Sodium

Silicon was left in the insoluble group where it was counted and partially identified, though this group was frequently contaminated with a small portion of various soluble isotopes.

This group separation procedure was very time-consuming, but in order to obtain reasonably accurate results on the per cent of various isotopes present at the time of collection, it was necessary to reduce the time for preparation of one or a few groups to less than 24 hours. This helped considerably, but even then it was difficult to correct for the decay of such short half-lived isotopes as Cu^{64}, As^{76}, Na^{24}, Mn^{56}, and Si^{31}.

Counting Methods

The measurement of radioactivity involved principally the selection of counting instruments and appurtenances; the development of counting techniques; the determination of the various correction factors such as geometry, air and mica-window absorption, and self-absorption; the development of decay curves; and the identification of beta emitters. Each of these is discussed briefly here and in detail in Appendix A.

Two types of counters were considered and tried for the routine beta activity density determinations; viz., the proportional or internal flow counter and the end-window Geiger-Muller tube counter. On the basis of the large sample load, the levels and type of activity encountered, and the previous experience of the General Electric Company at Hanford, the end-window G-M counter was selected for general use.

The most useful counting plate for routine beta counting was found to be a 1-inch stainless steel dish, designed to hold about 1 to 2 ml., and withstand high temperatures. Also, it was easy to mount close to and always in the same position under an end-window G-M tube. This plate was developed by the General Electric Company.

Sample counting time varied with the magnitude of the activity present. For routine water and biological samples a count of not less than 5 minutes nor longer than 15 minutes was normally adequate. Correction factors had to be applied to the counting rate to obtain absolute values of radioactivity, and these factors had to be measured and repeatedly checked.

In general the methods used for obtaining these factors were similar to those developed by General Electric Company (20). The same backscatter values were found to be applicable for this study since the same type of stainless steel plate was used for all beta counting. Absorption losses in the air, window and samples were determined by extrapolation from an aluminum absorption curve. Corrections for spread of source were made in terms of geometry of a point source by measuring the variation of counting rate across the end of the tube and integrating over the area of the source. The net geometry of the end-window G-M tube was determined from the known disintegration rate of a standard source and the observed and corrected counting rate of that source. Coincidence losses were determined by comparing the activity of eight small known sources, counted together, to the sum of the activity of the eight sources counted individually. Background was determined by overnight counting without a sample in the lead shield housing the G-M tube.

The amount of radioactive materials in the reactor cooling water effluent is continually decreasing due to decay. The influence of this decay is very important when short half-lived isotopes are still present in the river water, and the sample transport and preparation periods are large. A theoretical consideration could be given this correction factor, but due to the multiplicity of isotopes involved it appeared that an empirically derived decay curve would be preferable at each major sampling range and for each type of sample. Such a curve would permit correction for the time interval between collection in the river and the counting in the instrument. The method for deriving these curves involved, briefly, preparation of duplicate samples as quickly as possible and counting them at frequent intervals.

Results were plotted on semi-logarithmic paper, with activity versus time, and then, with a fair knowledge of the characteristics of the isotopes expected to be present, it was possible to extrapolate the curve back to time of collection. This was repeated many times at various river stages until it became apparent that a single average curve was satisfactory for routine use on any one kind of sample for any one location. Figure 19 shows some typical decay curves derived during these studies. The values are plotted in terms of the per cent activity remaining at any particular time, in hours, after collection.

Following the chemical breakdown of a sample into various groups, the radioactivity was measured as usual in the end-window G-M tube counters. The decay pattern and absorption curves were then established for all radioactive elements or groups of elements so as to determine the half-lives and energies which provide a means of identifying the beta particle emitters.

Very little counting for alpha particle emitters was done, inasmuch as materials creating that type of activity were not entering the river in large volumes. However, in order to define background conditions a few mud and water samples were examined for alpha emitters. This counting was done with an internal flow counter. The counting time varied with the amount of radioactivity present, the interval generally being somewhere between 5 and 32 minutes. The efficiency of the internal flow counter used was about 50 per cent. No corrections were necessary for spread of source, and air and mica-window absorption.

DISCUSSION OF RESULTS

The results of radioactivity counting indicate a wide variety of conditions in the stream. In order to adequately determine the influence of this activity, samples were collected at several locations above, within, and below the Hanford Works Reservation.

Radiological results on individual samples are presented in Appendix B. Charts showing average, maximum, and minimum results are included in this section.

Water

Water samples were collected routinely at Ranges C-400 and C-385 for background determinations. The gross beta activity at these sections, as well as at Roosevelt Lake (Range C-596 and above), was below the minimum

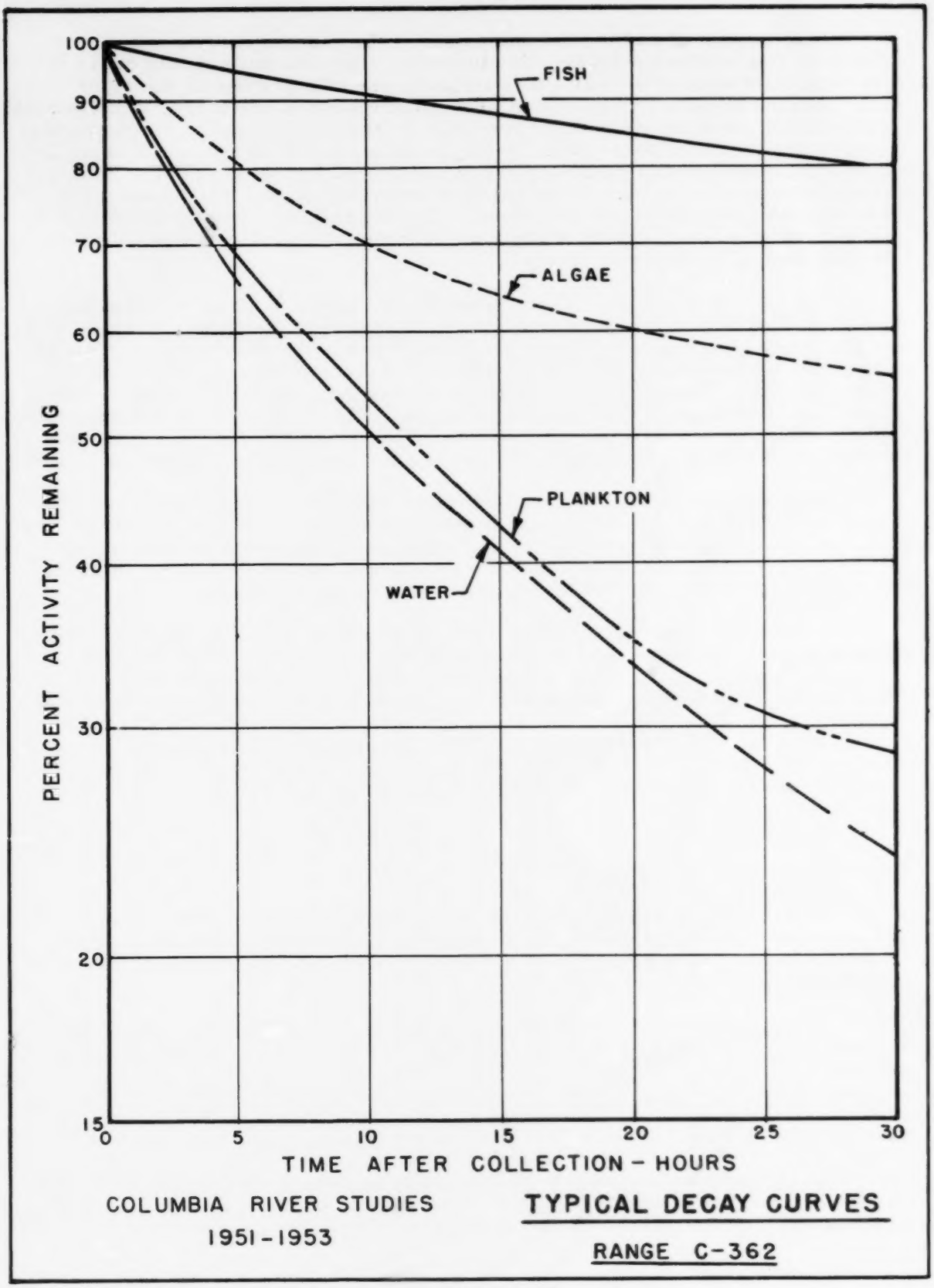

100
90
80
70
60
50
40
30
20
15
PERCENT ACTIVITY REMAINING
0
5
10
15
20
25
30
TIME AFTER COLLECTION - HOURS
FISH
ALGAE
PLANKTON
WATER
COLUMBIA RIVER STUDIES
1951-1953
TYPICAL DECAY CURVES
RANGE C-362

Figure 19

detectable limit of 2 counts per minute. This was found to be true when using either the internal flow or end-window G-M tube counters. For purposes of this study, therefore, datum or background level for water was considered to be less than 1×10^{-8} μc/ml. Some work on background levels has been done by the General Electric Company (21). A few traces of such naturally radioactive elements as uranium, radon, and radium have been found, but the quantities could not be accurately measured with the instruments available during this study.

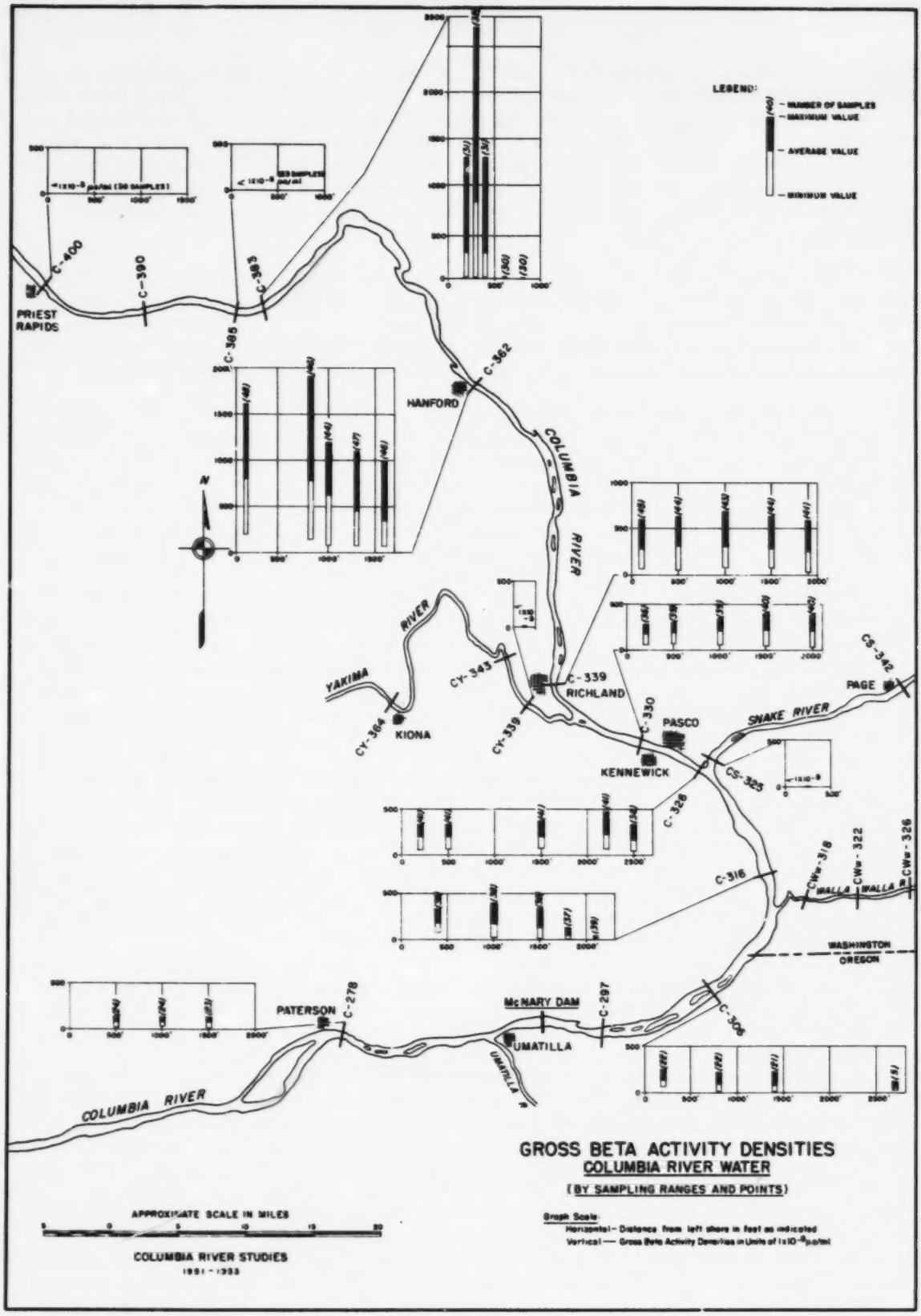
Previous studies (22) have shown that, because of the point-like discharge and the nature of the river currents, there is a large variation in the activity density across the river within the reservation. Further downstream, near Richland, the activity is uniformly spread across the stream. Figure 20 shows the distribution across the width of the stream at several sections.

The average value found at Range C-362, below all reactor effluents, was about 600×10^{-8} μc/ml. Proceeding downstream decay becomes a major factor in reducing the activity density. Average results at Range C-339, near Richland, were about 300×10^{-8} μc/ml. and rather evenly distributed across the width of the river. Results below Richland show the influence of the tributaries, but the distribution is uniform again below McNary Dam, on Range C-278. Average values at this point were about 75×10^{-8} μc/ml.

A few samples taken in the Bonneville Reservoir, between Ranges C-190 and C-155, show that decay and dilution have lowered the activity density to about 25×10^{-8} μc/ml. during normal low flows. Limited sampling near Portland, Range C-120, and Astoria, Range C-14, gave results of 5 to 10×10^{-8} μc/ml. in the tidal zone. Figure 21 presents the average variation in gross beta activity density for March and September 1952 between Range C-400, above the Hanford Works, and the mouth of the Columbia River.

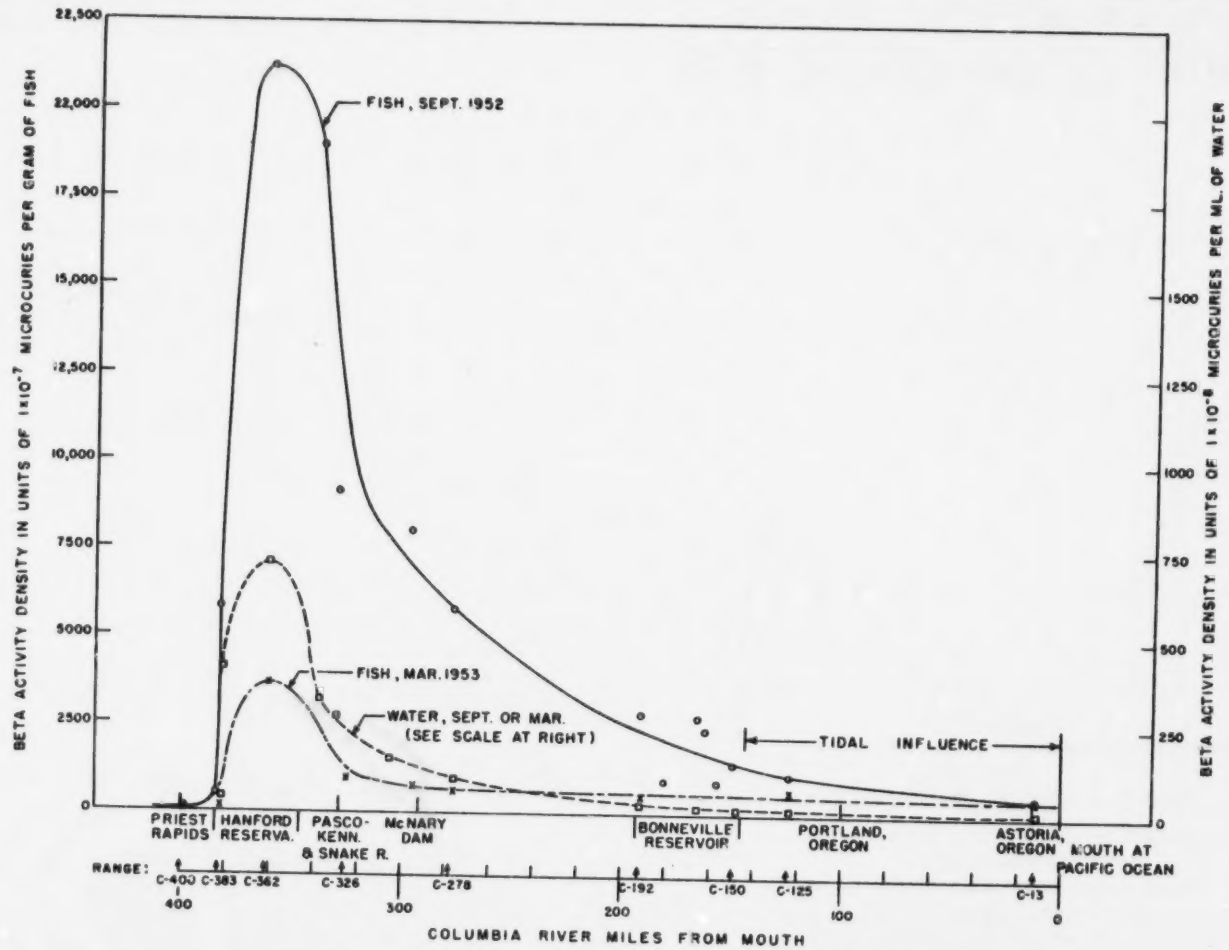
The wide spread in values at any one sampling point during any one month, such as 550 to $1{,}500 \times 10^{-8}$ μc/ml. at 100 feet from shore on Range C-362 during November 1951 (as shown in Appendix B), indicates that there is probably a corresponding variation in the amount of radioisotopes entering the river. There are certain factors within the plant itself which can contribute to this variation: (a) the quality of the coolant entering the piles; (b) the purging of the pipes carrying the coolant; and (c) the complete or partial shutdown of one or more piles for maintenance or other reasons.

Although the reasons for daily variation were sometimes not too clear from the stream data, it soon became evident from routine, weekly sampling that a major reason for the large changes in monthly average activity density, as shown in figure 22, was the fluctuation in the river discharge. For instance, the average activity density during May, June, and July is only from one-third to one-fourth of that observed during the remainder of the year. On the other hand, the river flow or dilution factor is three to five times higher those same three months than during the remainder of the year. Figure 20 also demonstrates that the Yakima River and, particularly, the Snake River, have a decided tendency to push the Columbia River water over and not mix completely until many miles below the confluence. This is especially true during the normal spring discharge of the Snake River, when the Columbia River is still at low flow. These tributaries add greatly to the dilution of the already highly diluted radioactive materials below the Pasco-Kennewick area.



GROSS BETA ACTIVITY DENSITIES
COLUMBIA RIVER WATER
(BY SAMPLING RANGES AND POINTS)

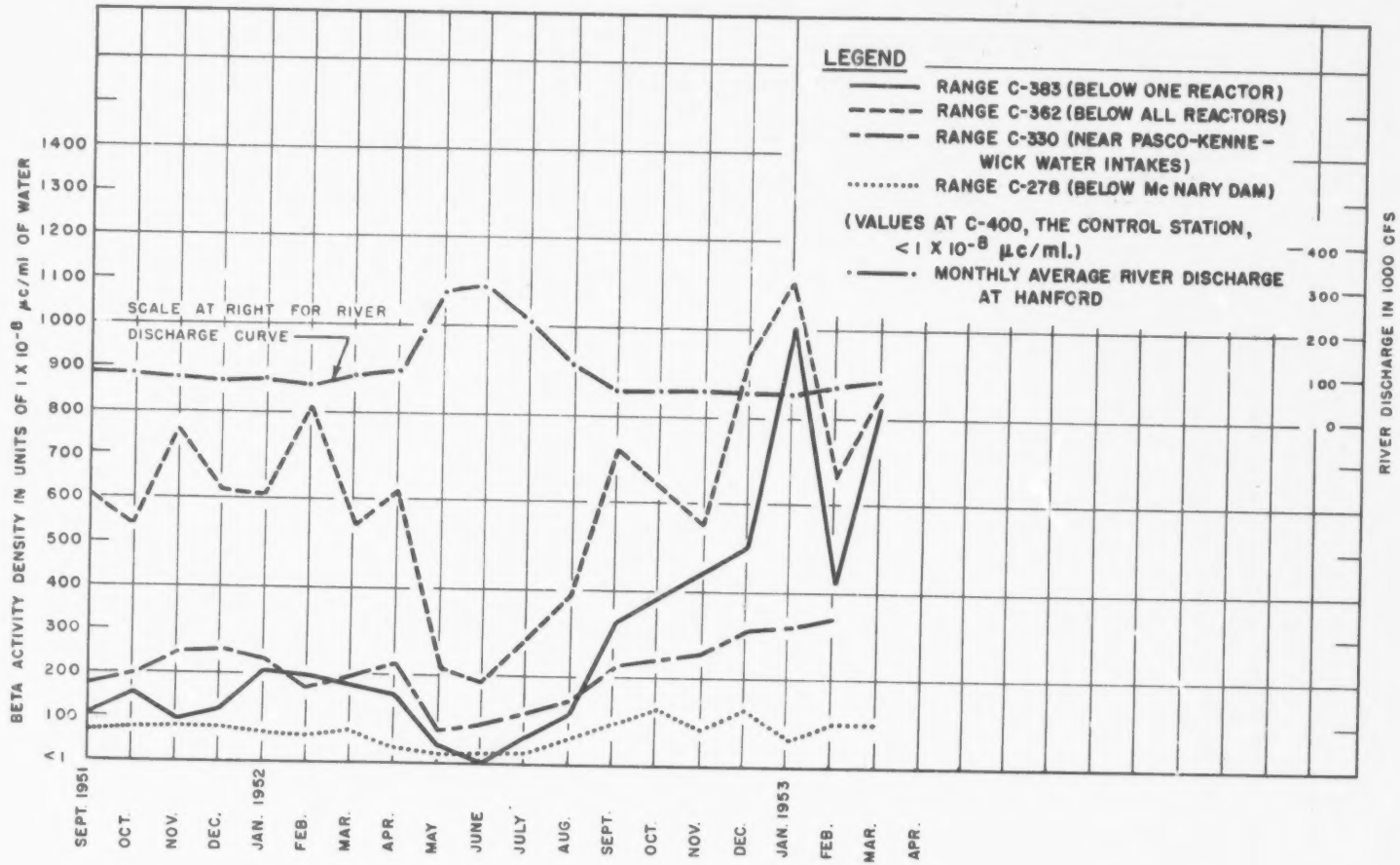
Figure 20



COLUMBIA RIVER STUDIES
1951 – 1953

VARIATION IN AVERAGE BETA ACTIVITY DENSITY WITH LOCATION IN RIVER

Figure 21



COLUMBIA RIVER STUDIES
1951 - 1953

BETA ACTIVITY DENSITY IN WATER

VARIATION BY SEASONS AND RANGES

Figure 22

Aquatic Organisms

A summary of radiological data for aquatic organisms is presented in graphic form. These charts show the maximum, minimum and average values for gross beta activity densities by sampling ranges, seasons and, where possible, by species of plankton, filamentous algae, bottom animals, juvenile fish and adult fish. The values for individual samples on which these summaries are based are given in Appendix B.

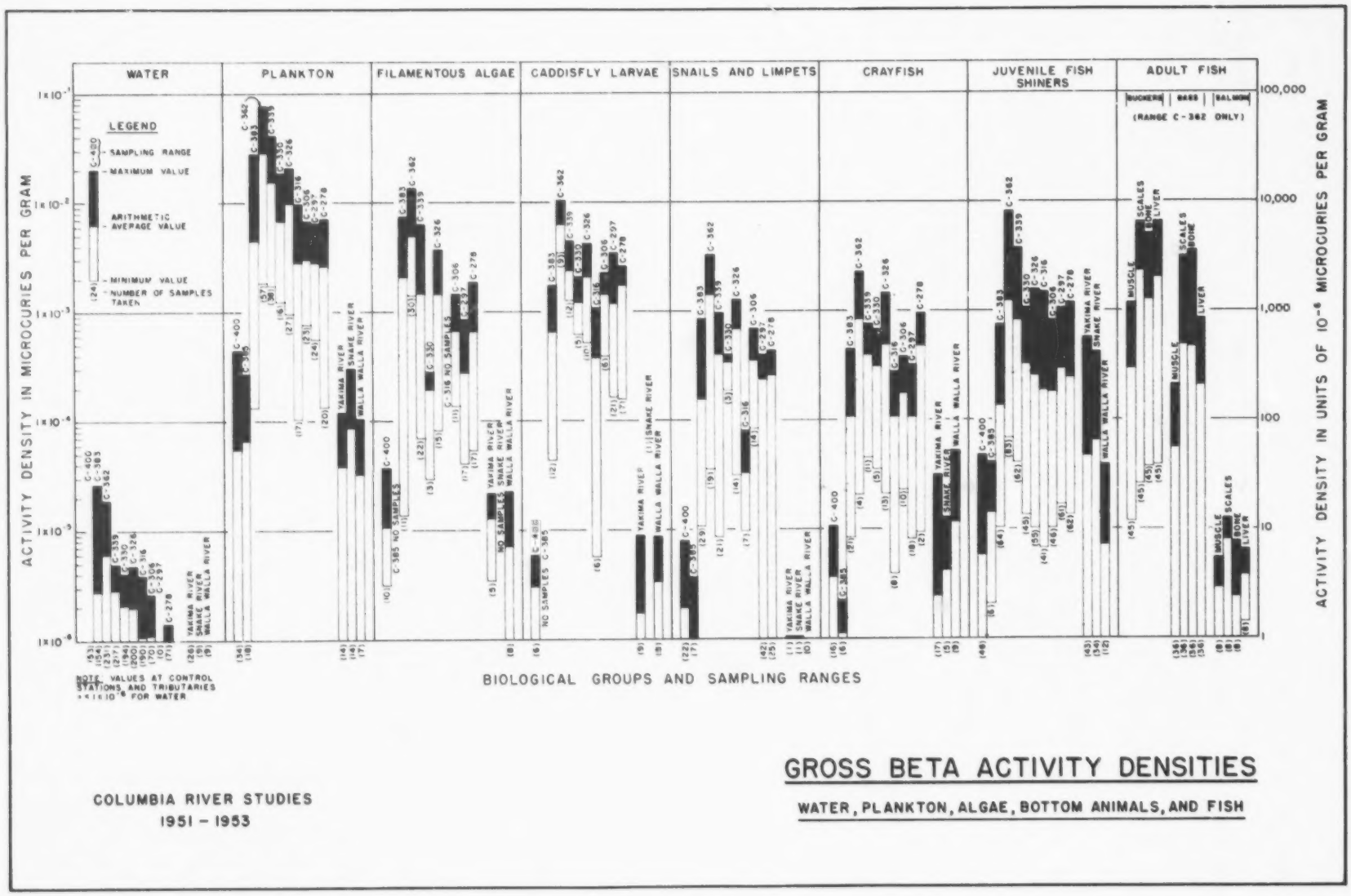
The minimum result shown on the charts is 1×10^{-6} μc/gm., as this value is near the minimum detectable limit for the various organisms. Some individual values as low as 1×10^{-7} μc/gm. are, however, given in Appendix B. The results for control stations and tributaries are shown in all charts. These values may in some samples be higher than normal background. Aquatic animals, principally fish, may be exposed to radioisotopes in the Hanford area and then migrate to control stations or tributaries. High values for fish taken at control stations and tributaries could only be attributed to this factor. In order to obtain samples entirely free from this effect, it would be necessary to take them above any fish migration. This could be done by collecting in an area such as Roosevelt Lake, where all migration upstream is completely eliminated by Grand Coulee Dam. Fish samples taken in that area all gave values of about 1×10^{-7} μc/gm., which probably reflect the normal natural background. It should be noted that on a few occasions results for plankton at control and tributary stations were considerably above the normal background. There was no readily apparent explanation for this change.

For comparative purposes, the maximum, minimum and average values for gross beta activity density in water and in the different groups of aquatic organisms at the various ranges are presented in figure 23. Seasonal variations and species differences are discussed below.

Plankton

Plankton organisms appear to concentrate radioactive materials to a marked degree, the averages of the levels observed at certain ranges being close to 10,000 times greater than those in the river water. As will be noted, the uptake of these materials by plankton was generally higher than for any other kind of organisms. The gross beta activity density varied from a low of less than 1×10^{-6} μc/gm., at control stations (Ranges C-400, C-385 and the tributaries) to a high of $77{,}000 \times 10^{-6}$ μc/gm at Range C-362, near Hanford and below all of the reactor areas. Proceeding downstream from this range, the sharpest drop in activity occurred between there and Range C-339, near Richland, with a more gradual decrease on down river. This can be attributed to the presence of fairly large quantities of short half-lived radioisotopes, in which activity had decreased through decay, and to dilution by major tributaries. Maximum activity values of $7{,}200 \times 10^{-6}$ μc/gm., however, were still present at Range C-278, nearly 100 miles downstream from Hanford.

The seasonal variation in activity densities of plankton, presented in figure 24, was quite large. Maximum values, occurring during low water periods from September to March, were up to 400 times the low values observed in May and June, the periods of highest stream flows. Activity levels in plankton seemed to be primarily dependent on activity density of the river water, as indicated in figure 23. The occurrence of high values in September,

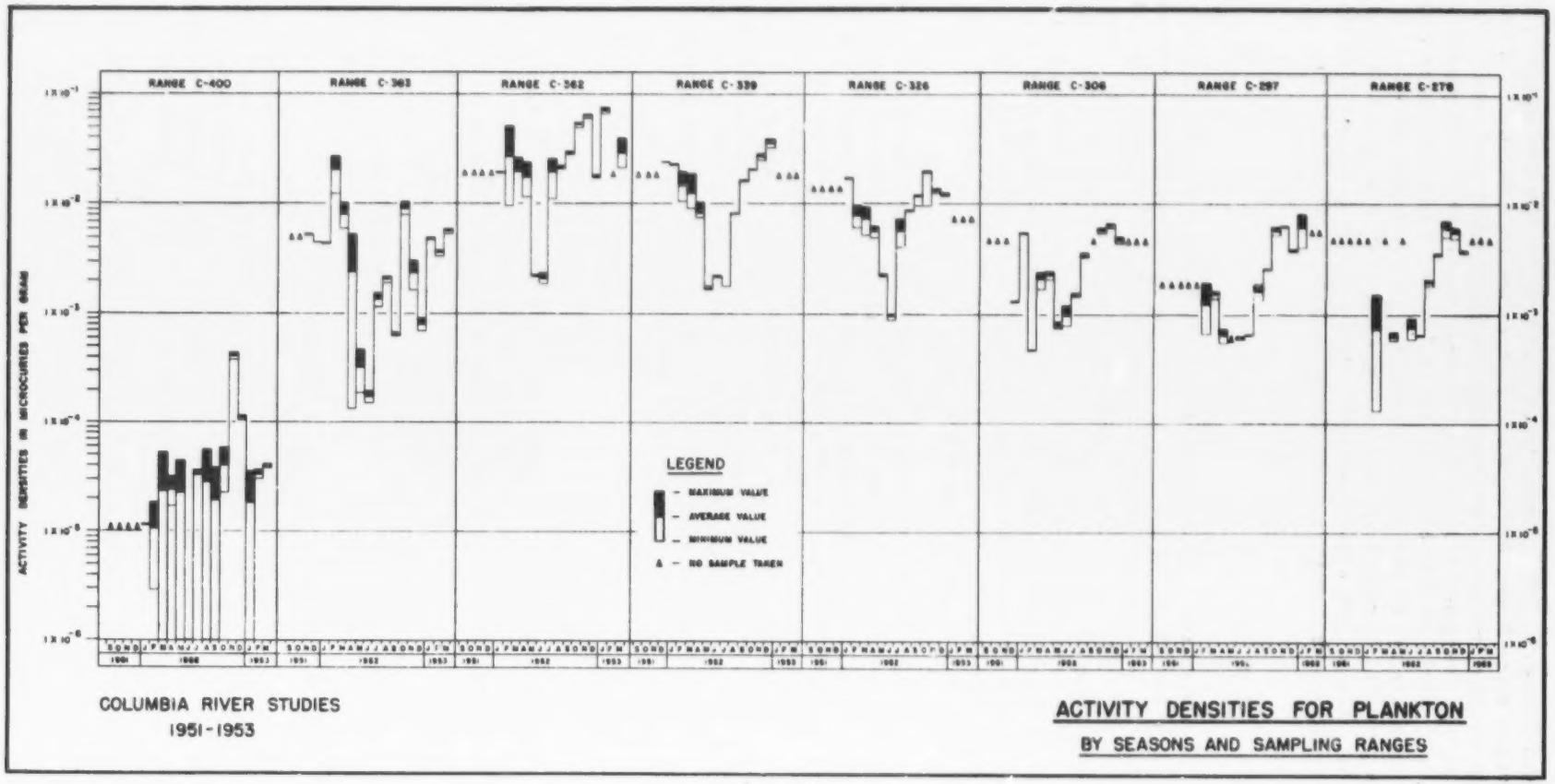


COLUMBIA RIVER STUDIES
1951 – 1953

GROSS BETA ACTIVITY DENSITIES

WATER, PLANKTON, ALGAE, BOTTOM ANIMALS, AND FISH

Figure 23



COLUMBIA RIVER STUDIES
1951-1953

ACTIVITY DENSITIES FOR PLANKTON
BY SEASONS AND SAMPLING RANGES

Figure 24

1952, and January, 1953, when river flows were low and activity densities of river water were high, discounts temperature as a factor. As has previously been shown, the temperature was high in September and low in January. At times abrupt changes of over 100 per cent would occur in plankton activity levels, with little or no change in river flows. These changes could be attributed mainly to a change in the activity levels of the stream waters. It is possible that the generic composition of the plankton would have some effect on activity densities. While this aspect was not studied it is believed that the overall effect would be very minor when compared with other factors.

Filamentous Algae

The variations in activity densities for filamentous algae, by sampling ranges, are shown in figure 23. These organisms readily concentrate radioisotopes, but to a lesser degree than plankton. Maximum values found were about 13,000 x 10^{-6} μc/gm., as against 77,000 x 10^{-6} μc/gm. for plankton. There appeared to be a more uniform decline in this activity between ranges, probably due to the presence of less short half-lived material in these vegetative forms than in the plankton, which is composed largely of diatoms. Values were definitely lowest during high water periods when water activity values were correspondingly low. The highest values were found during low flow periods when water activities were high.

There was no definite correlation with water temperatures. It is possible that the uptake of radioisotopes depends upon the rate of growth of a particular algal species and this in turn is dependent upon water temperatures. As some species may grow more readily at high water temperatures and others at low temperatures, this factor would have to be determined by work with a particular species. The observations in this study are too general and limited to make any conclusions in this regard. Based on the activity densities of several genera of filamentous algae it appears that the effect of water temperature on radioisotopic uptake is quite small, when compared to other factors.

Bottom Animals

Radiological data on bottom animals are limited, as samples were readily available only during low flow periods. Figure 23 shows the gross beta activity densities for caddisfly larvae, snails and crayfish, three of the most abundant and easily collected forms. Values up to a maximum of 10,000 x 10^{-6} μc/gm. were found in caddisfly larvae at Range C-362, with lower maximum values of 3,200 x 10^{-6} μc/gm for snails and 2,200 x 10^{-6} μc/gm. for crayfish. The few samples of other important bottom animals, such as midgefly larvae and mayfly nymphs, showed activity densities comparable to caddisfly larvae.

It is to be expected that higher activity densities would be found in insect larvae than in snails and crayfish as the caddisfly and midgefly larvae tend to feed directly on plankton and algae. While snails may feed on algae, they also utilize other materials such as decaying organic matter, and crayfish generally feed on animal material which usually contains less radioactivity.

The activity densities for snails were obtained from samples of whole

animals. A few samples were counted in which the individuals were removed from the shells and activity obtained separately for the shells and the body. The amount of activity in the shells was almost negligible when compared to that of the rest of the animal. Consequently, the activity densities given in this report are based on the weight of the whole snail and would be somewhat low when considered on the basis of fish food.

The maximum amounts of activity in bottom animals were found at Range C-362, with a progressive decrease downstream. This decrease, however, was smaller proportionately than in plankton and algae. This indicates the presence of a larger proportion of longer half-lived isotopes in these animals.

The results on bottom animals are not presented in graphic form by seasons. Data on individual samples show that the highest values were on samples collected in September, October and November. During these months river stages were low and water temperatures high, with radioactivity density in water also quite high. Later, during the winter months when the only change was a decrease in water temperatures, the radioactivity levels in these animals were lower. Lowest values, however, were found during high water stages when values for river water were also low. Since metabolic rates generally increase with elevation of water temperatures, the indications are that radioactivity levels in bottom animals are dependent upon their rates of metabolism as well as upon the activity density of the water.

Juvenile Fish

Gross beta activity densities in various species of juvenile fish, as well as the variations between ranges and seasons, are shown in figures 25 and 26. Because the samples were prepared from whole specimens of fish the amount and kind of food material contained in the stomach would have some effect on the results in individual cases. Also the migration or movement from areas of low level activity, such as sloughs and tributaries, would have an effect. For these reasons there was considerable variation in individual samples taken at the same time and place. The maximum activity, $13{,}000 \times 10^{-6}$ μc/gm., was found in suckers at Range C-362. The activity decreased uniformly downstream to a maximum of $1{,}800 \times 10^{-6}$ μc/gm. at Paterson, Range C-278. Minimum values at all ranges were near background levels.

The variation of activity levels between species was not much greater than between individuals of the same species. This might be expected as most of the fish in this age group feed on similar organisms. Shiners, dace, and suckers, which probably feed more extensively on plankton and algae than some of the other species, were among those having the highest activity levels.

The seasonal variations were quite pronounced. Maximum values occurred in all species in September and October, when activity densities and temperatures of river water were highest. Juvenile salmon, present only during the spring months, had activity values comparable with shiners at this season. Lowest levels occurred in February and March, when the water was coldest but water activity levels were still high. Some of the activity levels of fish during the winter season were only slightly above those at control stations. It was thus indicated that most of the activity in juvenile fish was

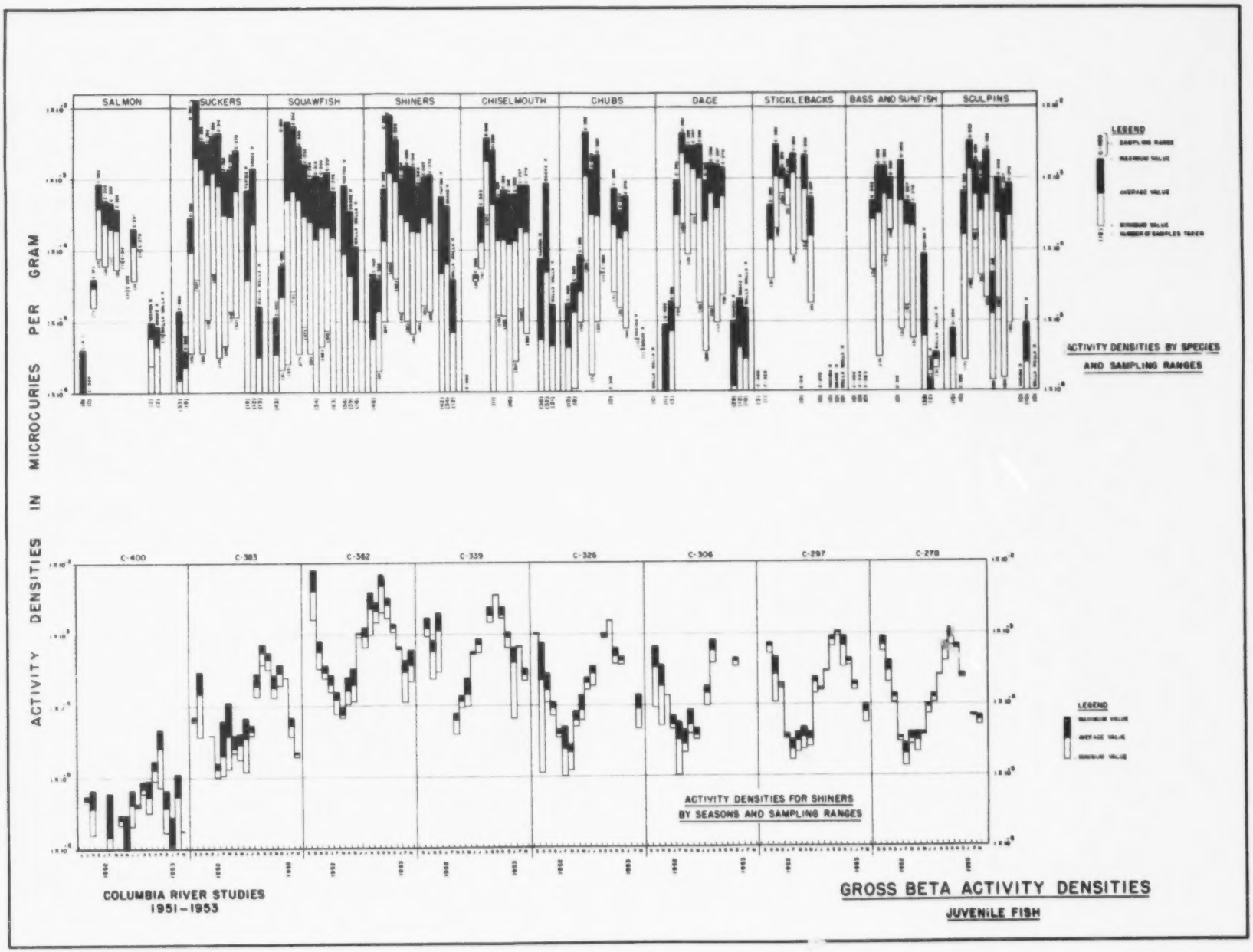
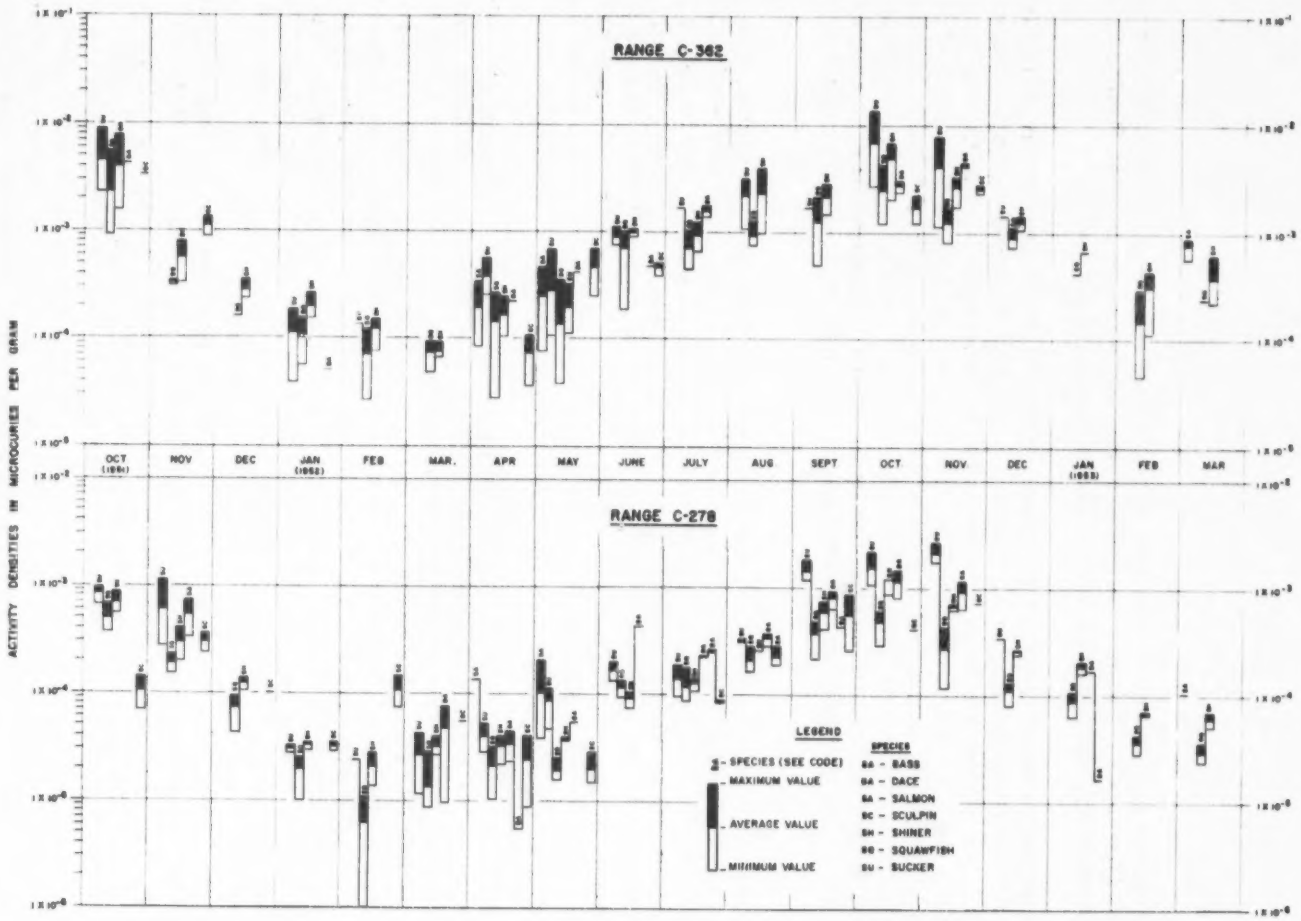

SALMON
SUCKERS
SQUAWFISH
SHINERS
CHISELMOUTH
CHUBS
DACE
STICKLEBACKS
BASS AND SUNFISH
SCULPINS
LEGEND
ACTIVITY DENSITIES BY SPECIES AND SAMPLING RANGES
ACTIVITY DENSITIES IN MICROCURIES PER GRAM
C-400
C-383
C-362
C-339
C-326
C-306
C-297
C-278
LEGEND
ACTIVITY DENSITIES FOR SHINERS BY SEASONS AND SAMPLING RANGES
COLUMBIA RIVER STUDIES
1951-1953
GROSS BETA ACTIVITY DENSITIES
JUVENILE FISH

Figure 25



COLUMBIA RIVER STUDIES
1951 – 1953

GROSS BETA ACTIVITY DENSITIES
JUVENILE FISH
BY SPECIES AND SEASONS

Figure 26

concentrated through feeding rather than by other processes, such as absorption through the skin or gills. Occasionally tributary samples showed activity levels considerably above established background values. This can be attributed to the migration or movement of a few individuals from the main stream.

Adult Fish

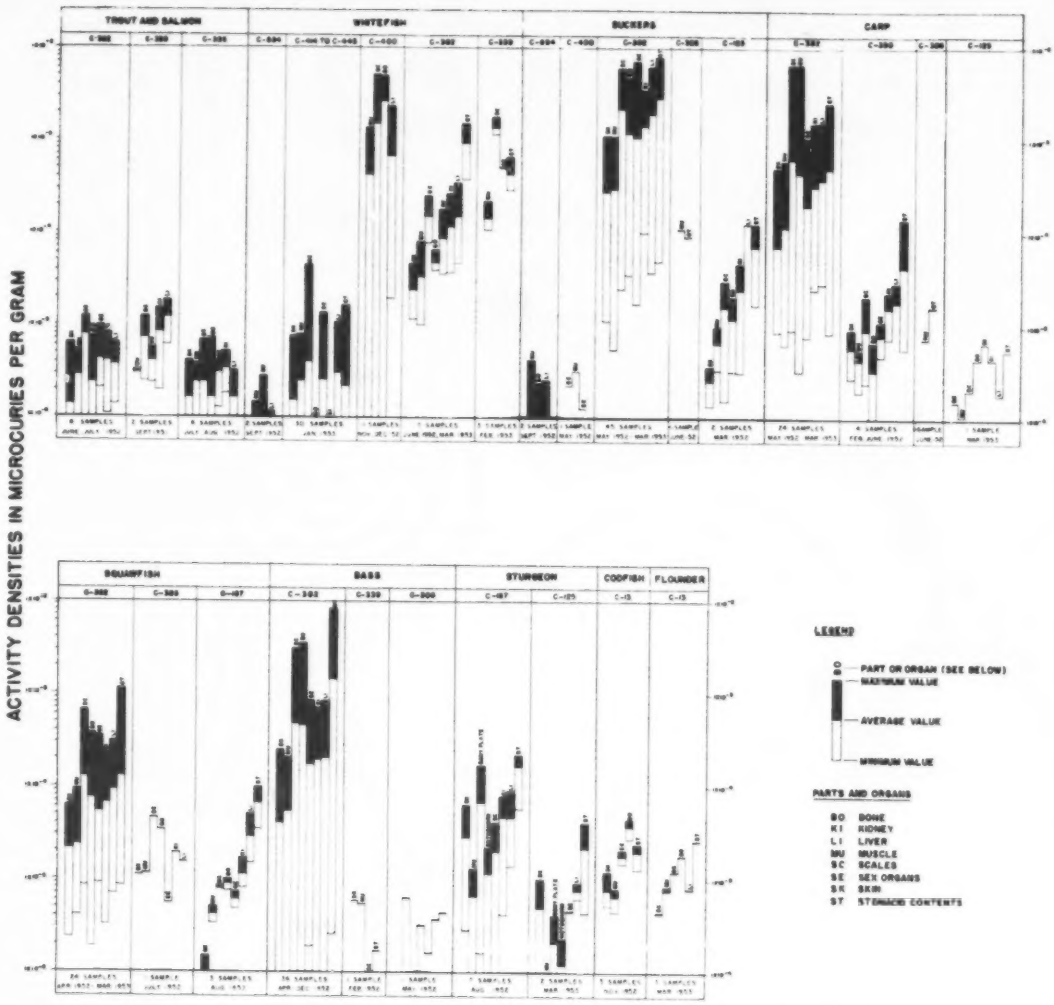
Radioactivity levels in various organs and other parts of adult fish are presented in figure 27. Extensive collections were made only at Range C-362 and consequently the data at the lower ranges are incomplete.

The observations indicate the same pattern as shown in juvenile fish; the higher activity values occur at Range C-362 and decrease progressively downstream. An exception to this was found in whitefish during the fall and early winter seasons. Data obtained by the General Electric Company (23) show activity levels in some individual whitefish to be as high above the Hanford Works area as immediately below all reactors. This indicates an upstream movement of some of these fish, probably for spawning purposes. Samples taken over 40 miles further upstream, however, indicate relatively low activity levels.

Highest values in adult fish samples were found in the scales, liver, bone, sex organs, kidney and stomach contents, with much lower results in the skin and muscle. Maximum values of 8,300 x 10^{-6} μc/gm. were found in the stomach contents, which included organisms on which the fish had fed. Maximum values of about 7,000 x 10^{-6} μc/gm. for individual samples were found in scales, bone, sex organs and livers, with slightly lower values for kidneys. Values for skin and muscle, the edible parts, were much lower and reached a maximum of 1,400 x 10^{-6} μc/gm. in the samples examined.

Seasonal variations in suckers and bass are shown in figure 28. Most of the higher results were found in individuals taken in the fall months, during the period of high water temperatures and low water stages. Samples of the same species taken earlier in the year, when river stages were higher and water temperatures lower, showed somewhat less accumulation of radioactivity. The lowest values were found during the winter months, when water temperatures were very low even though activity levels in the water remained high. It is thus evident that the radioactivity density in adult fish is dependent upon the rate of metabolism and the activity of the organisms upon which they feed.

A comparison of activity levels of various species can be made from figure 29. The data are shown for two different months, July and October, both periods of fairly high radioactivity levels in fish. Due to higher stream flows, however, activity levels in the water were much lower in July than in October. Values for suckers appeared to be higher than in other species. Next in order are carp, bass and squawfish. The first two of these, suckers and carp, are bottom feeders and their diet consists of a far larger portion of plankton, algae, and insect larvae than does the diet of bass and squawfish, which feed principally on aquatic animals such as crayfish and juvenile fish. All of these resident species were actively feeding at the time of collection and the radioactivity in their stomach contents was quite high. Blueback salmon, a migratory species taken at the same time and place showed very little radioactivity. No stomach contents were present in the salmon as the adults do not feed while in fresh waters.



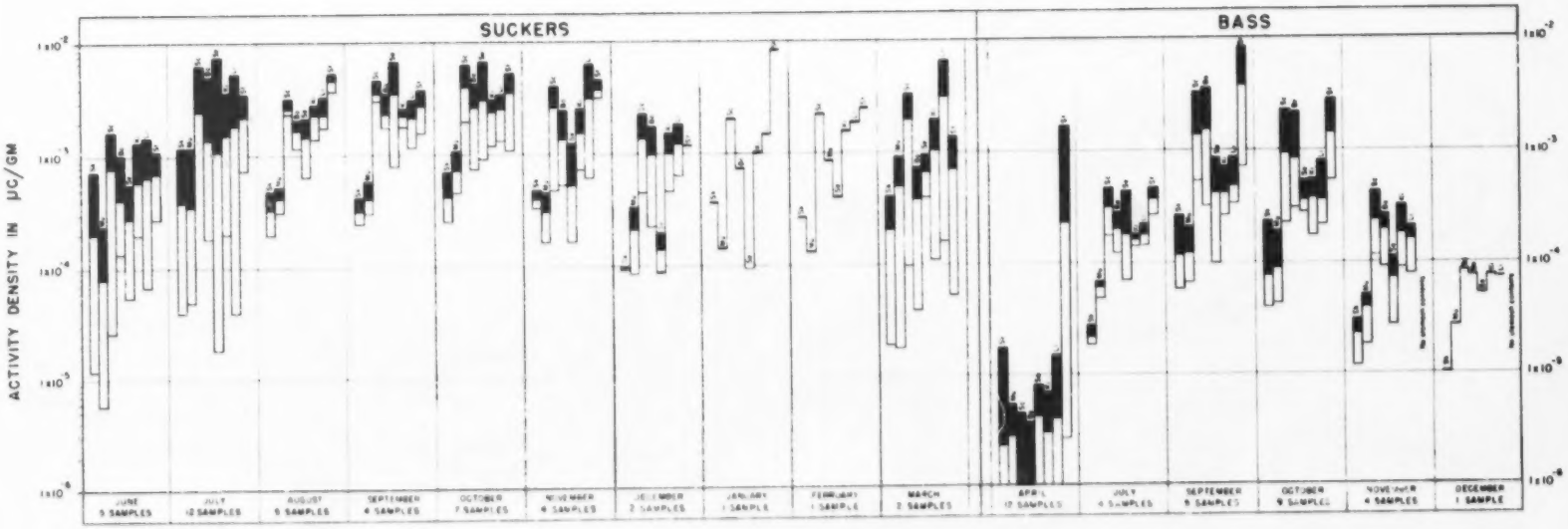
COLUMBIA RIVER STUDIES
1951–1953

GROSS BETA ACTIVITY DENSITIES

ADULT FISH—INDIVIDUAL PARTS

BY SPECIES AND SAMPLING RANGES

Figure 27



LEGEND

- PART OR ORGAN (SEE BELOW)
- MAXIMUM VALUE
- AVERAGE VALUE
- MINIMUM VALUE

PARTS AND ORGANS

- Bo BONE
- Ki KIDNEY
- Li LIVER
- Mu MUSCLE
- Sc SCALES
- Se SEX ORGANS
- Sk SKIN
- St STOMACH CONTENTS

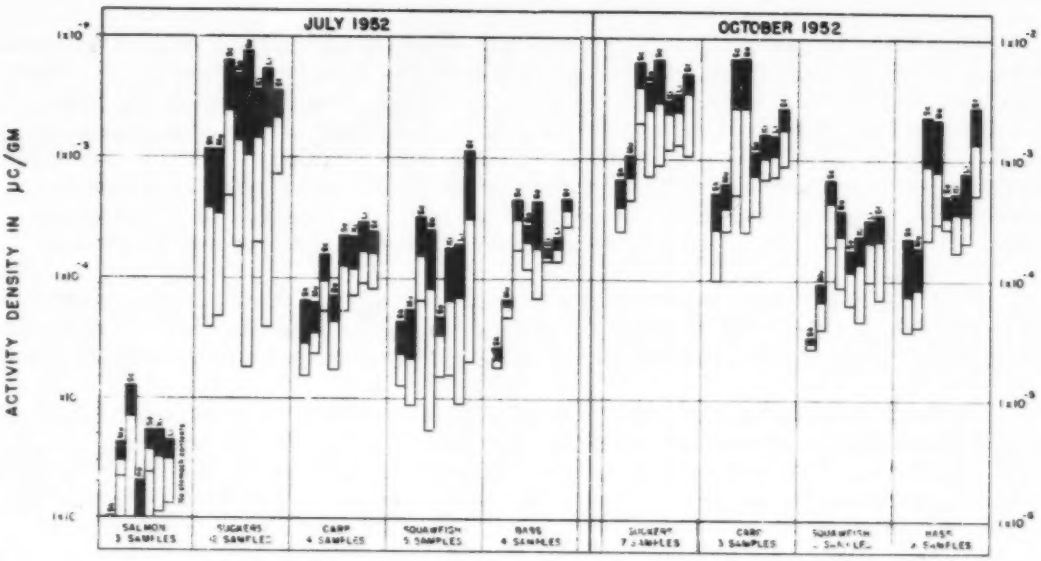
GROSS BETA ACTIVITY DENSITIES

ADULT FISH-INDIVIDUAL PARTS

RANGE C-362 BY SEASONS

COLUMBIA RIVER STUDIES
1951-1953

Figure 28



LEGEND

- PART OR ORGAN (SEE BELOW)
- MAXIMUM VALUE
- AVERAGE VALUE
- MINIMUM VALUE

PARTS AND ORGANS

- Bo BONE
- Ki KIDNEY
- Li LIVER
- Mu MUSCLE
- Sc SCALES
- Se SEX ORGANS
- Sk SKIN
- St STOMACH CONTENTS

GROSS BETA ACTIVITY DENSITIES

ADULT FISH-INDIVIDUAL PARTS

RANGE C-362 BY SPECIES

COLUMBIA RIVER STUDIES
1951-1953

Figure 29

Pattern of Accumulation of Radioactivity

The accumulation of radioactivity by aquatic organisms seems to follow a definite pattern, as illustrated by figure 30. This chart presents the seasonal variations in activity densities of water, various organisms and fish, as well as the changes in river flows and water temperatures, for Ranges C-362 and C-278.

Plankton (mostly phytoplankton) and filamentous algae, which absorb nutrients directly from the water, concentrate the most radioactivity. Next are bottom organisms which feed on this material, and then juvenile fish, which feed principally on these organisms. At the end of the chain are the adult fish which feed on the juveniles. There are, of course, some deviations from this pattern. Some fish feed directly on plankton, algae, and bottom animals, and would reflect higher values in individual samples. Crayfish, possibly feeding on some dead fish or other animals, reflect lower values.

It is evident from the data presented that activity levels in plankton and algae are directly dependent on the activity in the water, which is in turn dependent upon river flows and the amount of activity released into the stream.

On the other hand, activity levels in most aquatic animals are dependent upon their metabolic rates and the radioactivity values of the materials upon which they feed. Values for bottom animals were highest at low water stages and high water temperatures. There was a decrease in activity levels with lower water temperature, even though river stages remained low and the material upon which the animals feed remained high in activity. This decrease was most marked in fish.

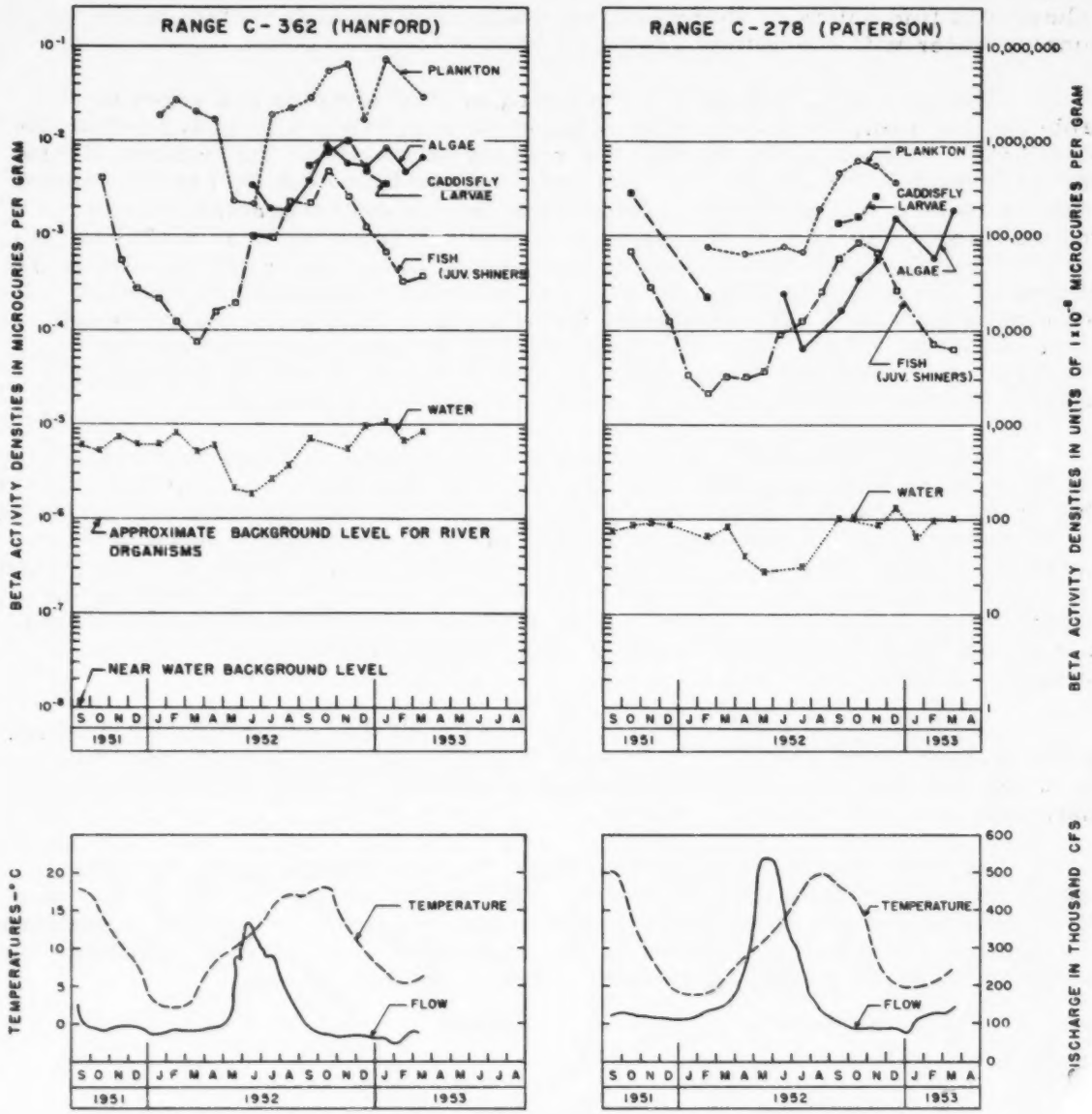
Some species, such as bass, which stop feeding at low water temperatures, showed very low activity levels during the winter months in spite of activity levels in the water remaining high. The activity levels in these fish rose rapidly with the resumption of conditions conducive to feeding, even though water activity levels decreased because of increased river flows. In other species, such as suckers and whitefish, which feed to some extent even during cold water periods, this is not so pronounced. Adult salmon, which do not feed while in these waters, contained little activity.

It is believed that most aquatic animals concentrate radioisotopes of the type encountered in the Columbia River through feeding rather than by other processes such as absorption through skin or gills.

Bottom Muds

Muds are generally not found in the swift-moving Columbia River and its tributaries, except near the shore during high water. The bottom of the main part of the stream is lined with rock and gravel, and even near shore or in slough areas the soil is chiefly a sandy or gravelly material. Consequently, only limited sampling was possible.

Since slight amounts of both alpha and beta emitters were anticipated in assaying the mud for radioactivity, background determinations for both were made on samples collected well above the Hanford Works. The technique used for alpha determinations included only the sum of uranium and plutonium



SEASONAL VARIATIONS

BETA ACTIVITY DENSITIES

COLUMBIA RIVER STUDIES
1951 — 1953

PLANKTON, ALGAE, CADDISFLY LARVAE, FISH, AND WATER

Figure 30

present, as these were the only alpha emitters anticipated. The beta determination was a rough estimate of the emitters that settled out by virtue of adhering to fine solids or those that were adsorbed through contact of the running water with the bottom gravel or sand.

The results of radioactivity counting of mud samples are given in table 2. The samples show a wide range of values, especially in and below the plant area. Alpha activity densities at control points above the Hanford Works varied from 1.8 to 5.7 x 10^{-7} μc/gm., while gross beta activity results ranged from 11 to 16 x 10^{-7} μc/gm. In the tributaries the corresponding results varied from 3.1 to 18 x 10^{-7} μc/gm. for alpha and from 17 to 36 x 10^{-7} μc/gm. for beta emitters, the highest values being found in the Snake River. Below the discharge of reactor cooling waters the results for alpha particle emitters were not significantly different from those found in samples taken above the plant and in the tributaries. Beta activity density immediately below the discharge of all reactor coolants, at Range C-362, varied from 39 to 830 x 10^{-7} μc/gm. Values below this section were well within these limits.

The most noticeable fact about the array of data for beta particle emitters is the wide range of values for any one location, such as at Range C-362. One of the reasons for this variation may be the change in activity density of the river water which had most recently contributed to the activity in the mud. Another possible reason for the variation may be that organisms may have been present to a greater extent in some samples than in others. Inasmuch as the organisms concentrate the radioactive materials many times it is conceivable that a small quantity of them could cause a considerable change from one sample to another.

In general, the gross beta activity density of the bottom muds decreases as the distance from the plant increases, but the change is less for mud than for water and biological organisms which contain many more short half-lived materials.

No radiochemical studies have been made to determine the specific radioisotopes in these mud samples since the gross activity density is low and the radioisotopes are difficult to remove or extract from the excessive quantities of residue. The decay pattern indicates the presence of a 40 to 50-day half-life isotope such as Fe^{59}, and a mixture of other long-life isotopes.

Radiochemical Group Analyses

Thus far the discussion has been confined to gross activity density measurements. Though it is necessary to establish and know these at all times, it is also important to know the quantity of each radioisotope that makes up this total. The public health significance of a radioactive material depends largely on the characteristics of the radioisotopes present. Some emitters may be harmful at a particular level while many others may not be of influence at the same level (24).

There are reasons to believe that some estimate of the type of emitters to be found in the pile effluent can be made from a knowledge of the chemical composition of the cooling water and the type of reaction taking place in the pile. On the other hand, an actual study of the situation demonstrates that this is extremely difficult to do, and that it is necessary to make repeated radiochemical

Table 2 - RADIOACTIVITY OF BOTTOM MUDS

Sampling Range	Location	Date	M.S.L. of River Stages near Range C-362	Activity Density 10^{-7} μc/gm.	
				Alpha	Beta
C-390	S. Shore	3/11/53	367'	1.8	11
C-387	S. Shore	2/18/53	367'	5.7	16
C-362	W. Shore	8/18/52	369'	3.5	200
		9/22/52	366'	4.5	39
		1/13/53	363'	6.5	830
		2/16/53	367'	5.2	220
		3/25/53	368'	5.4	200
C-339	N. Shore	1/13/53	363'	3.9	220
		2/26/53	367'	3.9	170
C-330	W. End Water Intake Bed	8/18/52	369'	2.8	21
		9/25/52	366'	4.8	35
	E. End Water Intake Bed	3/24/53	368'	5.4	250
C-306	S. Shore of Island	2/24/53	366'	8.5	190
C-191	3/4 Distance from N. Shore	8/25/52	---	--	160
		8/27/52	---	4.7	210
C-167	Mid-Stream	8/20/52	---	3.3	65
	3/4 Distance from N. Shore	8/20/52	---	1.8	45
		8/25/52	---	2.3	77
		8/27/52	---	5.3	130
C-150	Mid-Stream	8/20/52	---	2.3	1[illegible]
		8/25/52	---	5.9	87
		8/27/52	---	4.7	78
CY-339	S. Shore	2/16/53	---	6.3	29
		3/5/53	---	3.1	30
		3/24/53	---	5.8	17
CS-325	N. Shore	2/16/53	---	5.7	18
		3/24/53	---	18	36

analyses of the effluent to acquire knowledge regarding the amounts of various beta emitters present at any one season.

The findings of studies made by the General Electric Company (19) (25) were complete enough so that it was not necessary for the Public Health Service group to do extensive radiochemical analyses. However, a few samples were analyzed to become acquainted with the preparation procedure and to learn its effectiveness at small levels of activity. Group separations were made on samples of water and biological specimens all collected at Range C-362.

Table 3 summarizes the results. Values have been corrected for decay back to the time of collection and are tabulated on a percentage basis so that the results can be applied to the routine values reported for gross beta activity density. The percentages given in the following discussion apply to the soluble portion of the sample.

The major portion of the beta particle emitters in river water at Range C-362 is due to Cu^{64} with a half-life of 12.8 hours, As^{76} with a half-life of 26.8 hours, rare earths with various half-lives, and Na^{24} with a half-life of 15.1 hours. P^{32} accounts for only 1 to 3 per cent of the total. Mn^{56}, with a half-life of 2.6 hours, is reported to be responsible for an appreciable portion of the activity before the effluent enters the river (19) (25), but the flow and preparation time for samples is usually such that most of the activity due to this radioisotope has decayed and is thus not detected accurately. The results of 3 to 8 per cent are thus considered to be too low and the total recovery is not good when compared to the initial count of the entire soluble portion. Si^{31}, with a half-life of 2.8 hours, contributes to some of the activity in the insoluble portion, but it is also evident that a certain small percentage of all the soluble groups remains with the insoluble portion, for the two decay curve patterns are similar.

This situation was even more pronounced when analyzing plankton, where 10 to 14 per cent of the total activity remained in the insoluble portion. The large surface area of diatoms in such samples may have been the cause of this persistent adherence of radioisotopes to the undissolved material. This adsorbing process is probably the principal reason for the plankton samples containing so many short half-lived isotopes. For instance, Si^{31}, Cu^{64}, As^{76}, and Mn^{56} are usually responsible for most of the radioactivity in plankton samples from Range C-362. It is also possible that Na^{24} may be present in significant amounts at collection time, but it was the last major isotope to be chemically separated; consequently it had usually decayed to an undetectable level before counting. P^{32} and rare earths are each responsible for about 10 per cent of the total activity detected in the soluble portion.

On the other hand, P^{32} was the principal radioactive constituent found in attached filamentous algae. There was, however, a large spread, 42 to 87 per cent, in values. This spread in values can be attributed somewhat to the changing river stage which made it difficult to sample at the same location the year-round. A shutdown of one or more reactors could also very easily influence the amount of specific short half-lived isotopes in the water and algae.

Only one bottom organism sample was analyzed. It was found that 93 per cent of the activity was contributed by P^{32}, about 4 per cent by Cu^{64}, and the remainder somewhat equally by the other groups.

Table 3. RADIOCHEMICAL GROUP ANALYSES

SAMPLING DATA					Amount of Soluble Portion of Sample	Time Between Collection and Initial Counting (Hours)	Total Soluble Portion As % of Total Sample(1)	RECOVERY AS % OF TOTAL SOLUBLE PORTION(1) — Principal Radioactive Elements in Each Group								
Sampling Range	Mileage Index Number	Date and Time of Collection	Location of Sample	Type of Sample				Cu^{64}	As^{76}	P^{32}	Rare Earths	Fe^{59}, Cr^{51}	Zn^{65}, Mn^{56}	Ca^{45}, Sr^{89+90}, Ba^{140}	Na^{24} and Long-lived Isotopes	Total Recovery
Columbia River at Hanford	C-362	3-23-53 8:00 AM	100' from W. Shore	Water	3.5 L.	8	99	15	8.6	1.6	11	0.4	7.94	0.2	26	71
		3-30-53 8:00 AM			2.0 L.	7	87	16	18	3.3	6.0	0.7	3.34	0.1	6.1	54
		9-17-52 8:43 AM	Cross-section	Plankton	2 gms	6	86	34	0.3	13	14	1.5	2.9	0.1	0.9	67
		3-2-53 8:00 AM			1.25 gms.	6	87	24	9.6	11	4.4	1.4	5.3		1.3	57
		3-16-53 8:00 AM			1.25 gms.	7	90	25	6.5	11	10	1.4	7.0		0.7	62
		9-16-52 8:39 AM	W. Shore	Filamentous Algae (Ulothrix)	4 gms	28	94	4.2	4.4	58	6.0	2.6	1.4	0.1	0.8	77
		11-3-52 9:30 AM	Midson Island	" (Cladophora)	3 gms	6	96	2.9	10	42	1.5	0.2	5.0	0.1	3.7	66
		11-6-52 9:00 AM	W. Shore	" (Spirogyra)	2 gms	5	93	8.0			74				5.9	88
		2-9-53 9:00 AM		" (Ulothrix)	5 gms	7	90	4.7	1.1	87	3.2	0.3	1.2	0.1	0.8	98
		10-27-52 9:00 AM	W. Shore	Caddisfly Larvae	4 gms	30	91	4.3	<0.1	93	0.9	<0.1	0.9	<0.1	0.3	100
		8-4-52 9:30 AM	W. Shore	Fish (shiners, entire)	25 gms	49	>99.9	1.3	<0.1	75	0.2	0.4	0.1	0.1	0.1	78
		8-11-52 9:15 AM			10 gms	72	>99.9	<0.1	<0.1	56	0.4(2)	4.7(2)	0.2	0.1	0.3	61
		8-11-52 9:15 AM		Fish (shiners, entire without viscera)	<10 gms.	73	>99.9	0.3	<0.1	57	0.4(2)	9.6(2)	0.3	0.7	0.6	69
		10-13-52 8:00 AM		Fish (shiners, entire)	6.25 gms.	25	>99.9	<0.1	<0.1	92	<0.1	<0.1	<0.1	<0.1	0.9	93
		10-21-52 9:00 AM		Fish (squawfish, flesh)	20 gms	30	>99.9	<0.1	<0.1	96	<0.1	1.1	0.1	0.3	0.7	98

(1) All results adjusted to time of collection of sample

(2) Possibly a carry-over of P^{32}, since half-life was found to be approximately 14 days.

In fish the predominant radioactive material was P^{32}, the amounts varying from 56 to 96 per cent. Although the Fe^{59} group apparently accounted for 5 to 10 per cent in two samples it is believed that the results were due to a carryover of P^{32}. The half-life of the apparent Fe^{59} group was found to be about 14 days, as compared with 14.3 days for P^{32}. The actual half-life of Fe^{59} is 46 days.

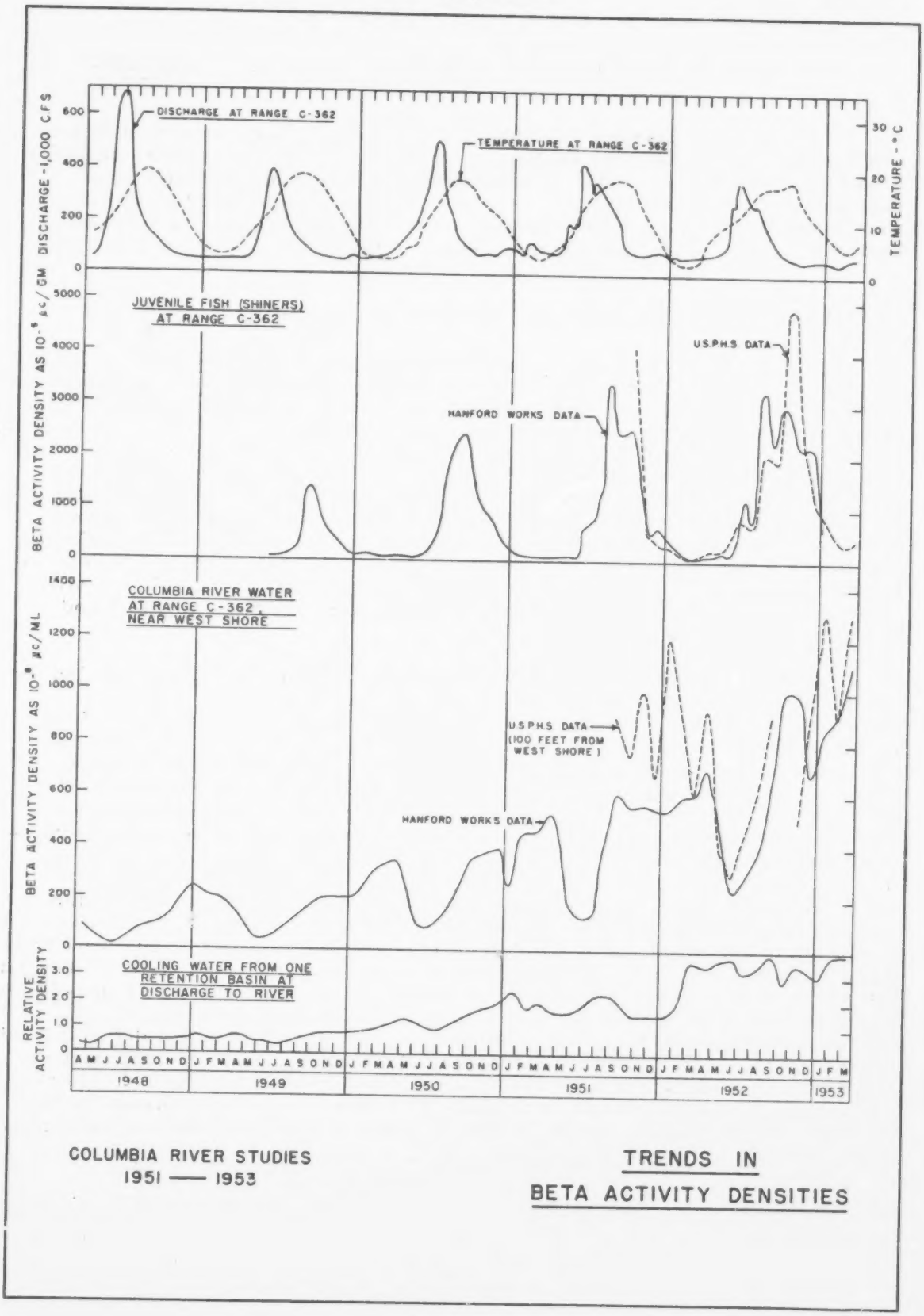
The radioisotopic content in the various samples shows that there are changes with each succeeding step in the fish food progression and that, with each step, P^{32} persists as the radioisotope of principal concern. Although group separations were not made on samples from downstream ranges, extending to the mouth of the Columbia River, examination of the gross decay curves on samples from all downstream locations show the activity to be principally from P^{32}. The predominance of this radioisotope may be due not only to the decay of short half-lived material but also to a shortage of available stable phosphorus for isotopic dilution and to the selective utilization of this element by the organisms.

TRENDS IN ACTIVITY DENSITIES

The radioactivity of wastes entering the Columbia River from the Hanford Works has been under constant surveillance by the Atomic Energy Commission's prime contractors since the start of plant operations. The information, based on samples taken at Range C-362 (near the west shore) during the 5-year period from April 1948 through March 1953, is presented in figure 31. The chart shows the temperature, flow, and gross beta activity density for water and juvenile fish. In addition there is also shown the relative activity density of the effluent from one of the reactor coolant retention basins at the point of discharge to the Columbia River. For purposes of comparison the Public Health Service data obtained during the survey period, for river water and juvenile fish at a point 100 feet from the west shore, are also included.

Since 1948 the activity density of the effluent reaching the river has shown a constant increase, and as would be expected, this increase is reflected in the results on the river water and juvenile fish.

Variations in temperatures and flows are those normally expected with seasonal changes. Peak radioactivity levels in the fish correspond more closely with high water temperatures, while peak levels in the river water correspond with the low flows.



COLUMBIA RIVER STUDIES
1951 —— 1953

TRENDS IN
BETA ACTIVITY DENSITIES

Figure 31

CHAPTER VIII

EFFECTS OF RADIOACTIVITY ON STREAM QUALITY AND USE

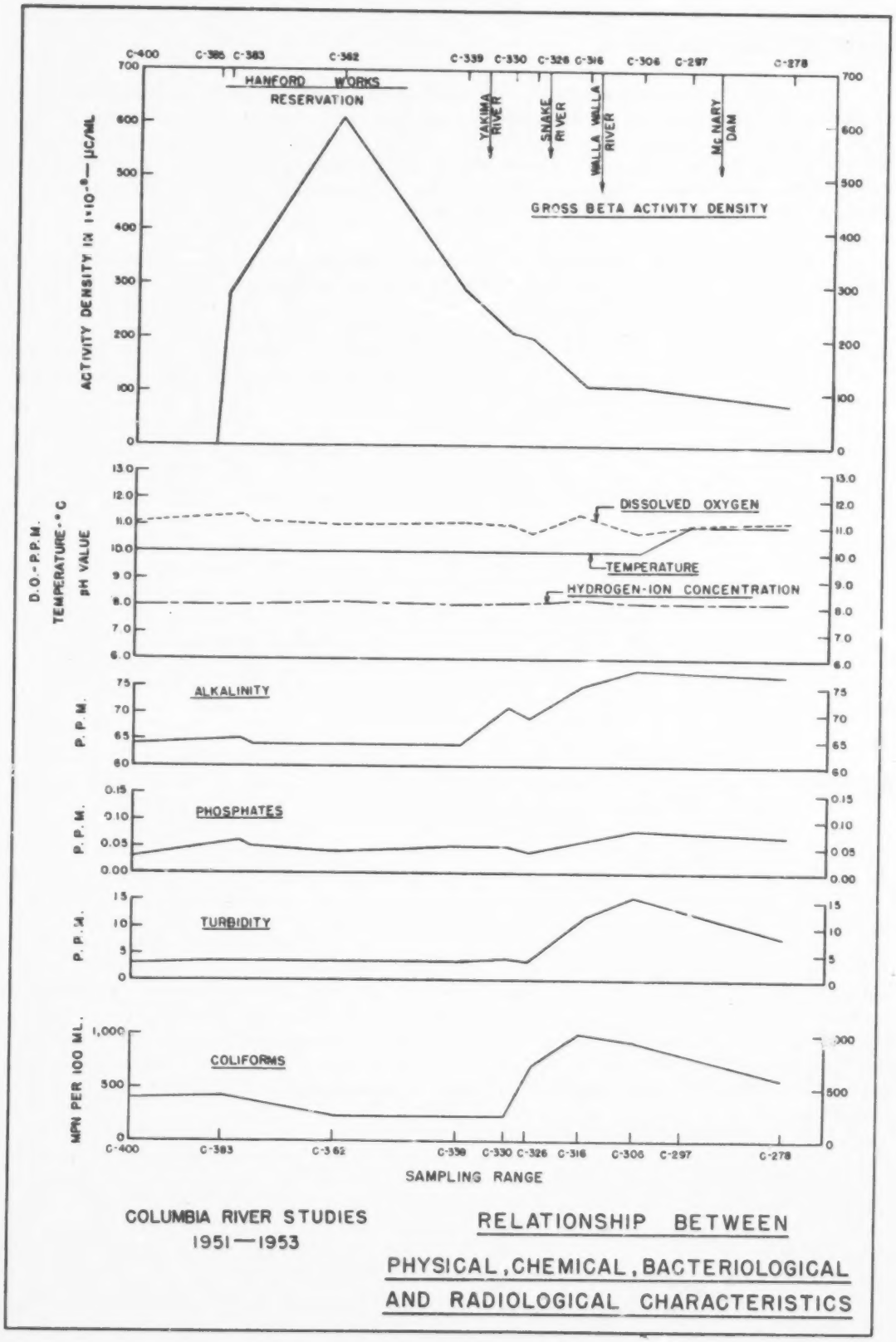
No large discharges enter the Columbia River between Priest Rapids and Richland, other than the cooling waters from the Hanford Works reactors. This was therefore a suitable location in which to measure the effects of radioactivity upon the chemical, physical, bacteriological, and biological characteristics of the stream. These various characteristics have been presented in preceding sections of this report. The effects are discussed below.

CHEMICAL, PHYSICAL, AND BACTERIOLOGICAL CHARACTERISTICS

Figure 32 presents the relationship between gross beta activity density results, in the Priest Rapids to Paterson section, and the more important water quality parameters. Each curve shows the average value for all data collected at each cross-section during the period September 1951 to April 1953, inclusive. From this it is evident that though activities increased as much as a thousandfold in some instances there was no significant influence on the dissolved oxygen, temperature, pH, alkalinity, ammonia, turbidity, sulfates, phosphates, and coliform density at Range C-362. Continuing downstream other factors influence the water quality, such as the entrance of the Yakima, Snake, and Walla Walla Rivers, and the discharge of sewage from the Pasco - Kennewick area. However, the results downstream from Range C-339 still show no apparent effect of the radioactivity on the chemical, physical and bacteriological characteristics.

The Atomic Energy Commission's prime contractors have sampled the Columbia River, both above and below the Hanford Works, since 1944 to determine the physical, chemical, and bacteriological characteristics of the stream. The physical and chemical data have been averaged by months and are presented in figure 12. The absence of any significant effect on these characteristics is again evident, in spite of a gradual rise in radioactivity levels of the river water, as shown in figure 31. The variations in some of these parameters are those normally expected as a result of seasonal changes in temperature and runoff.

Although there is no apparent significant effect on temperature, the cooling water is thermally hot when discharged to the river. There is evidence of a localized effect at the point of discharge but due to the swift currents and large dilution there is a rapid mixing and little, if any, overall effect on temperature is evident. There were very few occasions when as much as a one-degree increase was found in the immediate vicinity of the submerged outlets. In general, any temperature changes after adequate mixing were not detectable with the type of field thermometer used during the studies. While a comparison of monthly average temperatures for 1951-1952 and 1952-1953 may indicate an increase in the latter season, temperatures at the control sections and in the atmosphere show this to be due to milder weather conditions during the second winter period.



COLUMBIA RIVER STUDIES
1951—1953

RELATIONSHIP BETWEEN
PHYSICAL, CHEMICAL, BACTERIOLOGICAL
AND RADIOLOGICAL CHARACTERISTICS

Figure 32

AQUATIC POPULATIONS

In determining the effects of radioactive effluents on aquatic organisms, the amount and kinds of radioactivity and the radioisotopes from which this activity is derived are very important. Plants and animals selectively absorb and utilize specific nutrients from their surrounding medium. The amounts of radioactive materials concentrated in the various aquatic organisms is dependent upon the activity in these nutrients.

Radiochemical analyses and decay studies, previously discussed, have shown that P^{32} is by far the most important radioisotope assimilated by aquatic organisms. The radioactive materials in pile effluent water and in river water near the reactor areas consist principally of short half-lived isotopes such as Mn^{56}, Cu^{64}, Na^{24}, As^{76}, with a relatively small percentage of P^{32}. This last isotope is selectively concentrated many times and to varying degrees (23) by these organisms.

Radiochemical analyses have indicated that a large percentage of the radioactivity in plankton (mostly diatoms) at Range C-362 is due to Na^{24} and Cu^{64}, probably by adsorption on the siliceous materials, while only 10 per cent is due to P^{32}. However, at ranges further downstream a much larger percentage is from P^{32}. While the activity density of the free floating plankton forms is greater than for other aquatic organisms, their life is short, their size is small, the time of maximum exposure is short, and the decay is rapid. There is no evidence that present levels of radioactivity have any effect on these organisms. Work carried out by the General Electric Company (23) and the University of Washington (26) has shown radioactivity levels many times those present in the Columbia River to have no apparent effect on various kinds of plankton microorganisms.

Filamentous algae contain a much smaller proportion of short half-lived radioisotopes, the major portion found in samples at all ranges being P^{32}. It has been demonstrated (23) that algae grow readily in water containing much greater amounts of radioactive materials than the amounts found in the Columbia River; hence no effects would be expected at present stream levels. The major effects from both plankton and filamentous algae would be due to their ability to concentrate radioisotopes and pass it on to higher forms in the food chain. In bottom animals the largest amount of radioactivity is from P^{32}, although small quantities may be from short half-lived materials in the immediate vicinity of the reactors. These animals can concentrate radioisotopes and pass it on to the larger forms, as shown by the results obtained by the General Electric Company (27) and the Public Health Service. Little information is available on the maximum quantities of radioactive materials that may be harmful to them but amounts several times those now present in the river have shown no apparent effect on snails and crayfish (14).

The principal radioisotope in fish is P^{32}, due mainly from feeding on other organisms. Laboratory studies (13) (14) have demonstrated that Na^{24} may be concentrated directly from waters containing 5 per cent or more of reactor effluent, while P^{32} is concentrated principally by ingestion of radioactive food materials. It has further been demonstrated (23) that waters containing up to 10 per cent reactor effluent have no apparent effect on trout and salmon eggs, fry, or fingerlings due to the radioactivity present. The field studies reported here have indicated no apparent effect of radioactivity on fish populations.

In summary, then, it can be stated that radioactivity levels found in the Columbia River during these studies have had no apparent immediate effect on aquatic populations. It is entirely possible, however, that higher levels may have some effect on fish or on one of the links in their food chain. Characteristics of the pile effluent, other than radioactivity, may also have some effect on the organisms. It is believed, on the basis of laboratory demonstrations (13) (14), that concentrations of 5 to 10 per cent reactor discharge may have a detrimental effect on salmon and trout spawning due to temperature conditions or to toxicity from chemicals used in the water treatment. However, such conditions do not presently exist in the Columbia River. The matter continues to be observed and studied by the General Electric Company, and reviewed by the local State authorities.

WATER SUPPLIES

The type and quantity of radioisotopes that enter and are removed by downstream domestic water treatment systems have been matters of concern to the Atomic Energy Commission and its prime contractors since the start of plant operations. Two water supply intakes lie in the Columbia River some 30 miles below all reactor discharges. Though this matter may seem somewhat removed from the problem under study, namely the effects of radioactivity on stream quality parameters, it nevertheless is closely related and warrants discussion.

The city of Pasco, with a population of approximately 12,000, has a water consumption that varies from 1 million gallons daily in winter to over 7 million gallons daily during the hot summer months. The design capacity of the plant is 6 million gallons daily. Due to lack of adequate storage facilities there were times when the rapid sand filtration plant was overloaded. Therefore, a few years ago an effort was made to lengthen the filter runs by changing the medium in some of the filters from sand to Anthrafilt.

Because of the McNary impoundment a dike has been constructed along the city of Pasco waterfront and the location of the water intake changed. No information is available as to the quality entering the plant from the new location. However, prior to impoundment the water was being pumped from near the north bank at Range C-330. The quality has been discussed previously in this report. The gross beta activity density of the influent averages about 100×10^{-8} μc/ml., for the high water periods, and around 300×10^{-8} μc/ml. during the remainder of the year.

The results of a special study (28) conducted by the General Electric Company in August 1951 showed that the influent water had a gross beta activity density of 700 to 800×10^{-8} μc/ml. as against a value of 50×10^{-8} μc/ml. in the effluent. The various treatment units in the plant each remove some of the radioactive materials, but the major portion was eliminated in the coagulation process. Activity of the sludge in the coagulation basins was in the order of 250×10^{-6} μc/gm. The material that does not settle out by coagulation eventually concentrates as a mat on the filters. Activity of the sludge in the filter back wash water was $1{,}300 \times 10^{-6}$ μc/gm. while the activity in the filter media was found to be 40×10^{-6} μc/gm. A high percentage of Cu^{64}, As^{76}, and P^{32} was found in the backwash sludge, indicating good removal of these isotopes. The plant is monitored routinely by the General Electric Company, with results showing 50 to 95 per cent removal of radioactive materials.

The water intake and treatment system for the city of Kennewick, across the river from the Pasco intake, consists essentially of a man-made infiltration gallery on Clover Island. The source is supplemented by a well on the island near the infiltration beds. The system has been greatly overloaded due to a rapid population growth and lack of proper distribution facilities. However, improvements are being made rapidly. The supply is routinely monitored by the General Electric Company, with results showing a high percentage of reduction in radioactive materials between the river and the distribution system. The gross beta activity density of the water in the system is generally below 1×10^{-7} μc/ml.

PUBLIC HEALTH SIGNIFICANCE

Excessive ionizing radiation has long been recognized as a health hazard. Observations and studies of the damaging effects of X-rays and radium have provided a basis for establishing the first set of limits for various types of radiation. With the advent of nuclear reactors and atomic bombs many other radioisotopes were identified, and the need for more specific knowledge regarding their effect on man and his environment soon became apparent.

To meet this need research programs have been and continue to be carried out at many places throughout the world. Review of past and current efforts in this field is made periodically by various committees of radiation specialists. Some review and approve permissible doses for external sources, some for X-rays, some for internal doses, etc., so that the working occupational limits to be used are safe and yet the most practical ones possible in the light of available knowledge.

Maximum Permissible Concentrations

In order to evaluate the significance of the radioactivity levels found in the Columbia River, or any other surface water under study, it is necessary to know the maximum permissible doses presently established for the human body. Such information is available from many sources. The Subcommittee on Permissible Internal Dose of the National Committee on Radiation Protection, sponsored by the National Bureau of Standards, has recently prepared a handbook (24) in which the information has been summarized, both for air and water. This is presently the most authoritative source for this material.

The Subcommittee states that, "Because, in general, it is impossible to predict at the start how long a person will be exposed, permissible limits must be set on the assumption that the occupational exposure will continue throughout the working life of the individual and environmental exposures will continue for a lifetime. The values given in this report have been derived on the basis of continuous exposures for a lifetime (the effective half-lives of the radioisotopes considered in this report, with the exception of Ra^{226}, Sm^{151}, Pu^{239}, and Sr^{90} are so short that the time of exposure is not critical in the calculations and the same maximum permissible concentrations in air and in water are obtained regardless of whether the exposure is for 30 years of occupational exposure, 70 years lifetime, or an infinite period) or for the equilibrium condition in which the rate of elimination has become equal to the rate of deposition in the body in all cases except for Ra^{226}, Sm^{151}, and Pu^{239}. Therefore, their use as interim values for a period of several years is fully justified. If future

information indicates that these values should be more or less conservative, they can be adjusted before anyone has been unduly inconvenienced or before damage can be expected to result. In any case, because of the uncertainties involved in the present values and in determining the actual accumulation and potential hazard of radioisotopes in the human body, it is strongly recommended that exposure be kept at a minimum insofar as it is practicable. Bearing in mind that in the future it may become necessary to lower some permissible limits, it is suggested that a factor of safety that may be as large as ten be used in the design and operation of permanent installations where large quantities of radioactive material are involved. This is particularly important in cases in which provision of additional protection later would be very difficult and expensive."

There are essentially 10 factors that determine the hazards of radioisotopes and thus aid in determining the maximum permissible concentrations. These are as follows:

(a) Quantities available
(b) Initial body retention
(c) Fraction going from blood to critical body tissue
(d) Radiosensitivity of tissue
(e) Size of critical organ

(f) Essentiality of the critical organ to the proper function of the body
(g) Biological half-life
(h) Radioactive half-lives of intermediate length
(i) Energy of the radiation produced by the radioisotope
(j) Specific ionization and attenuation of energy in tissue

Table 4 has been prepared from the National Bureau of Standards information for the purpose of indicating the relative hazard of various isotopes, including those found in the Columbia River. For a mixture of unknown radioisotopes a maximum permissible concentration of 1×10^{-7} μc/ml. has been established for beta or gamma emitters in water. This, of course, is only a general guide line. When most of the radioisotopes in a sample have been specifically identified then the values given in table 4 are to be used as working limits.

Water

Although a complete radiochemical analysis of river waters downstream from the plant is rather difficult to perform because of dilution and decay, a reasonably accurate estimate of the maximum permissible concentration for Columbia River water can be made. Data are available on the radiochemical content of pile coolant effluent (19) (29) and of river water at Range C-362, as given in table 3. Applying the radiochemical data to the equations given in Appendix 1 of NBS Handbook 52 (24) the maximum permissible concentration, using a factor of safety of 10 as recommended by the Subcommittee, is found to be 4×10^{-4} μc/ml. The average gross beta activity density for the highest 13-week period, as shown at Range C-362 below all reactors, was found to be 8×10^{-6} μc/ml., or one-fiftieth of the maximum permissible concentration. In the Pasco - Kennewick area the corresponding gross beta activity density

Table 4. MAXIMUM PERMISSIBLE AMOUNT OF RADIOISOTOPE IN TOTAL BODY AND MAXIMUM PERMISSIBLE CONCENTRATION IN AIR AND WATER FOR CONTINUOUS EXPOSURE (Excerpts from NBS Handbook 52)

A. Common Radioisotopes that are Alpha Emitters

Element	Organ, gm	Microcuries in Total Body	Microcuries per Milliliter of Water
Po^{210} (sol)	Spleen, 150	0.02	3×10^{-5}
Rn^{222} + dr	Body, 7×10^{4}		2×10^{-6}
Ra^{226} + $\frac{1}{2}$dr	Bone, 7×10^{3}	0.01	4×10^{-8}
U-Natural (sol)	Kidneys, 300	0.2	7×10^{-5} (a)
U^{233} (sol)	Bone, 7×10^{3}	0.04	1.5×10^{-4}
Pu^{239}	Bone, 7×10^{3}	0.04	1.5×10^{-6}

B. Beta and Gamma-emitting Radioisotopes that are of interest because they are common body elements

Element and Percentage in Body	Organ, gm	Microcuries in Total Body	Microcuries per Milliliter of Water
H^{3}(HTO or $H^{3}_{2}O$) 10%	Total Body, 7×10^{4}	10^{4}	0.2
C^{14} (CO_2)	(Fat, 10^{4} (Bone, 7×10^{3}	250 1,500	3×10^{-3} 4×10^{-3}
Na^{24}, 0.15%	Total Body, 7×10^{4}	15	8×10^{-3}
P^{32}, 1.0%	Bone, 7×10^{3}	10	2×10^{-4}
S^{35}, 0.25%	Skin, 2×10^{3}	100	5×10^{-3}
Cl^{36}, 0.15%	Total Body, 7×10^{4}	200	2×10^{-3}
K^{42}, 0.35%	Muscle, 3×10^{4}	20	1×10^{-2}
Ca^{45}	Bone, 7×10^{3}	65	5×10^{-4}
Mn^{56}, 3×10^{-4}%	(Kidneys, 300 (Liver, 1×10^{3}	2 7.5	0.15 0.3

B. Beta and Gamma-emitting Radioisotopes that are of interest because they are common body elements (continued)

Element and Percentage in Body	Organ, gm	Microcuries in Total Body	Microcuries per Milliliter of Water
(Fe^{55} (Fe^{59} 0.004%	Blood, 5×10^{3} Blood, 5×10^{3}	1×10^{3} 11	4×10^{-3} 1×10^{-4}
Cu^{64}, 2×10^{-4}%	Liver, 1.7×10^{3}	1.5×10^{2}	8×10^{-2}
Zn^{65}, 0.003%	Bone, 7×10^{3}	430	6×10^{-2}
I^{131}, 4×10^{-5}%	Thyroid, 20	0.3	3×10^{-5}

C. Other Radioisotopes of Current Interest

Cr^{51}	Kidneys, 300	390	0.5
Co^{60}	Liver, 1.7×10^{3}	3	2×10^{-2}
As^{76}	Kidneys, 300	10	0.2
Sr^{89}	Bone, 7×10^{3}	2	7×10^{-5}
Sr^{90} + Y^{90}	Bone, 7×10^{3}	1	8×10^{-7}
Y^{91}	Bone, 7×10^{3}	15	0.2
Ru^{106} + Rh^{106}	Kidneys, 300	4	0.1
Ag^{105}	Liver, 1.7×10^{3}	18	2
Cs^{137} + Ba^{137}	Muscle, 3×10^{4}	90	1.5×10^{-3}
Ba^{140} + La^{140}	Bone, 7×10^{3}	5	2×10^{-3}
La^{140}	Bone, 7×10^{3}	24	1
Ce^{144} + Pr^{144}	Bone, 7×10^{3}	5	4×10^{-2}
Pm^{147}	Bone, 7×10^{3}	120	1

(a) Chemical Toxicity

averages 3×10^{-6} μc/ml., or less than one-hundredth of the maximum permissible concentration.

It is pointed out that this evaluation is based on the radioisotopic composition of the Hanford reactor coolant effluents and the Columbia River during these particular studies. In evaluating some other problem the equations given in Appendix 1 of NBS Handbook 52 are to be applied to the pertinent conditions and locations.

Aquatic Organisms

As aquatic organisms may concentrate radioactive materials many times above the levels found in water, the use of these organisms, such as fish, for human or animal consumption presents a potential public health problem. Fortunately, most of the radioactivity in fish is from P^{32}, a relatively short half-lived isotope, so that natural decay helps in reducing the activity before the fish is consumed. Also, a large portion of the activity is in parts of the fish not utilized for food, such as the scales, bone and internal organs. Based on a maximum permissible concentration of 200×10^{-6} μc/ml. and an average daily water intake of 2,200 ml. (24) the maximum permissible intake of P^{32} amounts to 0.44 μc per day. The average activity levels for the highest 13-week period, in the muscle of a game fish such as bass, was 100×10^{-6} μc/gm. while in suckers it was 500×10^{-6} μc/gm. The migratory species, such as salmon, do not appear important from this standpoint, as very little radioactive material is concentrated in the adults.

While the daily intake of fish flesh required to ingest the maximum permissible concentration of radioactive materials can be computed on the basis of the results obtained during this survey, such a figure would not be too realistic. It must be realized that few, if any, humans would eat the indicated amount of fish daily over a lifetime. The fish are not eaten immediately after being caught, some time elapsing for cleaning, cooking, and other preparation. Thus the actual permissible intake would be greater than that computed.

CHAPTER IX

EFFECTS OF IMPOUNDMENTS ON STREAM QUALITY

Limited surveys were made on two existing Columbia River reservoirs to obtain information which would assist in predicting the effects of McNary and other impoundments on water quality characteristics. Such work included, essentially, the collection of samples of water, aquatic organisms, and bottom muds for determination of existing physical, chemical, biological, and radiological conditions above and within the reservoirs.

Roosevelt Lake is a deep, multiple purpose type of impoundment, with maximum depths up to about 385 feet. The other impoundment, Bonneville Reservoir, is a relatively shallow, "run-of-the-river" type, with maximum depths up to about 100 feet. All of the proposed reservoir projects on the Columbia River would fall somewhere between these two extremes.

The two surveys will be discussed separately, followed by a discussion of expected effects in the McNary Reservoir. Complete reports on the surveys are given in Appendix C and Appendix D, respectively.

ROOSEVELT LAKE STUDY

The studies in Roosevelt Lake were made during the periods September 22 and October 1, 1952, and April 13 and 14, 1953, both of which were during low river flow conditions. In the first survey the reservoir was full and water temperatures were at a maximum, while during the second short period water stages were at a minimum, 54 feet below normal, and water temperatures were also at or near minimum values.

The more important changes indicated in the physical and chemical characteristics, during the above periods, were as follows:

1. A decrease in the suspended materials load from the upper to the lower reservoir. The change from a turbulent, relatively shallow stream with few large pools to a wide deep pool with practically no current would naturally have the effect of dropping silt loads and thus clarifying the water. While this is quite evident during periods of low river flows and practically all the suspended material is dropped, the large volume of water and the higher velocities during high flow periods keep some of this material in suspension through the reservoir.

2. An increase in surface water temperatures from upper to lower sections of the reservoir. While there appeared to be little or no thermal stratification anywhere within the lake during the surveys, an increase of 3 to 4°C. was found in the water temperatures between the upstream and downstream parts of the reservoir. This may be a seasonal occurrence, during low river flow periods. More extensive temperature studies at other seasons would be needed to definitely establish the pattern.

3. A slight decrease in dissolved oxygen saturation values, especially in the deeper waters. However, only one area in which a definite oxygen deficiency occurred was found during this study, and this was in a tributary.

4. A very slight increase in free CO_2 values from surface to deeper waters, with a corresponding decrease in pH values.

5. A possible increase in iron and manganese content in the deeper waters in the downstream portion of the reservoir.

From the biological standpoint there were definite changes in conditions as compared to those found in normal or unimpounded sections of the stream. The more significant changes included:

1. Zooplankton organisms (especially copepods and cladocerans), which are very limited under normal river conditions, appeared to be fairly abundant during the fall season, especially in the lower reservoir.

2. Phytoplankton populations, which were very limited during the fall season, indicated some build-up in the lower reservoir during the early spring. This increase was almost entirely due to one diatom, Asterionella sp. which is considered a filter clogging type. This could have some effect on downstream water supplies.

3. Bottom organisms, such as caddisfly and mayfly larvae, which are very abundant in unimpounded parts of the river, were replaced almost entirely by oligochaetes and midgefly larvae, less desirable types from the fish food standpoint.

4. From the standpoint of sports or food fish, populations were of a much less desirable type than those found outside the reservoir. This is probably due to the exclusion of migratory species by Grand Coulee Dam and to certain productivity factors.

The major reasons for the change in biological characteristics and the poor productivity in this impoundment are the annual deposition of suspended material, especially in the upper reaches; the sharp drop-off at the shore line, giving very few areas of shallow water; and the large winter and spring drawdowns, which limit aquatic vegetation and bottom fauna, and may affect fish reproduction.

While the waters were found to be of good bacterial quality the studies were insufficient to show any effects due to the impoundment.

As no sources of radioactivity were known to be above this reservoir, radiological studies were confined to background determinations, which were at or near minimum detectable levels.

BONNEVILLE RESERVOIR STUDY

A study of Bonneville Reservoir was made from August 18 to 29, 1952, inclusive, a period of low river flows and high water temperatures. As the

greatest concentrations of chemical constituents and highest biological activity would be expected during this period, the maximum effects due to impoundment would probably be indicated. While changes of a nature similar to those in Roosevelt Lake occurred, the degree of change was considerably less in this shallow "run-of-the-river" type of impoundment. This was due to the much smaller storage capacity, the higher current velocity and much less fluctuation of water levels than occur in Roosevelt Lake.

The more significant changes in the physical and chemical characteristics, evident from this study, were as follows:

1. Some deposition of suspended material occurred within the reservoir. While turbidity values were similar throughout, the waters in the upper areas visibly contained more fine sand and silt and large bottom deposits of silt and fine sand were found throughout the area.

2. A very slight temperature increase was found between the upper and lower reservoir. There was no evidence of any thermal or chemical stratification, however.

3. Some chemical conditions, while not noticeably different between the upper and lower reservoir, were significantly different from those found in the Priest Rapids to Paterson section of the river. Among these differences were increases in ammonia, iron, pH, and alkalinity. It is believed that these differences are not due to the impoundment but, rather, to a build-up in the river between the two locations.

Biologically, the major effect appeared to be a definite change in bottom fauna. This area appears much less productive than unimpounded areas of the river. The most abundant organisms, as in Roosevelt Lake, were oligochaete worms and midgefly larvae. The change to these less desirable forms would probably have little or no effect on adults of anadromous species of fish, such as salmon, since the adults are not feeding while in these waters. Adequate provisions, such as fish ladders and elevators, are made to assure the passage of these fish over the dam. Young salmon, however, which are feeding for short periods on their way down river may be affected, as possibly will certain resident game species. The physical condition of the pool, with the very steep shores, quite sandy areas and large amounts of woody debris in the bottom, would also tend to discourage resident fish populations.

Plankton conditions did not appear to be appreciably changed within the impoundment during the study. It is possible that at other seasons the impoundment may have some effect. However, with the short holdup time of river water in this pool and the current velocity of from 1 to 2 miles per hour, this effect would not be very significant.

The bacterial water quality depended on sources of domestic pollution within the reservoir and no definite effect could be determined due to impoundment.

The radioactive materials entering this reservoir originate at the Hanford Works, some 150 miles upstream. As the average flow time from this source to the reservoir it 60 to 70 hours, most of the activity is from isotopes

having fairly long half-lives, principally P^{32}. As the river holdup time within the reservoir is only a matter of hours, this impoundment would not be expected to have much effect. There is some decrease in activity in the water from the upper to the lower reservoir but not significantly greater than in a similar section of the unimpounded river. The activity in the various aquatic organisms does not significantly change within the impoundment.

EFFECTS FROM THE McNARY IMPOUNDMENT

Since the McNary impoundment is a relatively shallow, "run-of-the-river" one, its behavior can be expected to be more nearly like that of the Bonneville Reservoir than of Roosevelt Lake. There are, however, certain major differences between the McNary and Bonneville pools.

Several factors present in the McNary Reservoir may increase biological productivity over that found in the other impoundments. There will be fairly extensive shallow water areas, the tributaries entering the reservoir are quite fertile, and the drawdown will be held to a minimum. These factors should encourage fish food organisms and allow for natural reproduction of various species of fish. Provision is made for migration of fish by means of ladders at McNary Dam.

Additional effects as indicated in other impoundments may also apply here. A part of the silt and fine sand load will be dropped, thus clarifying the water to some extent but also causing unfavorable bottom conditions in certain areas. It is also probable that a small water temperature increase may occur. It is not expected that major chemical and physical changes will take place as a result of the impoundment. As has been previously discussed, the tributaries entering this area have some effect on this aspect of the water quality.

The effects of radioactivity in the McNary Reservoir should not differ too greatly from those found in the Bonneville Reservoir, prior to the impoundment at McNary. While McNary is much closer to the discharges of reactor cooling waters, there will be a considerable increase in travel time, in comparison to conditions prior to full operation.

The backwaters of the new reservoir will reach to Range C-354, where reductions in velocity will begin. On the basis of a discharge of 70,000 c.f.s. at Range C-362 the flow time from there to the Pasco and Kennewick water supply intakes at Range C-330 will be increased from 13 to 26 hours. The flow time from Range C-362 to McNary Dam, at Mile 292, will be increased from 32 to 170 hours.

The data indicate that fine silt and diatoms tend to adsorb radioisotopes. Since McNary will have more shallow areas than does Bonneville the net effect is expected to result in a faster accumulation of radioactivity in the bottom muds and animals. With the increase in travel time and consequent decay of the short half-lived radioisotopes the activity in the McNary Reservoir will be due principally to P^{32}, Rare Earths and Fe^{59}.

GLOSSARY

ABSORPTION: The process by which the number of particles or quanta in a beam of radiation is reduced or degraded in energy as it passes through some medium. The absorbed radiation may be transformed into mass, other radiation, or energy by interaction with the electrons or nuclei of the atoms upon which it impinges.

ACTIVITY DENSITY: The activity of either a specified radioisotope or a mixture of radioisotopes in a unit quantity of matter. It will normally be expressed as microcuries per gram (μc/gm.) for solid samples and as microcuries per milliliter (μc/ml.) for liquid samples.

A.E.C.: U. S. Atomic Energy Commission.

BACKGROUND RADIATION: Radiation arising from sources other than the one directly under consideration. In electrical measurements of radioactivity and nuclear phenomena, the term usually refers to those undesired counts or currents that arise from cosmic rays, local contaminating radioactivity, insulator leakage, amplifier noise, power line fluctuation, and other sources.

BACKSCATTERING: The deflection of particles or of radiation by scattering processes through angles greater than 90° with respect to the original direction of motion. In the assay of radioactivity it applies to the scattering of particles into the measuring device by the material upon which the sample is mounted.

BETA PARTICLE: Charged particle emitted from the nucleus of an atom and having a mass and charge equal in magnitude to those of the electron.

BIOLOGICAL HALF-LIFE (of a radioactive substance): The time in which a living tissue, organ, or individual eliminates, through biological processes, one-half of a given amount of a substance which has been introduced into it. (See also EFFECTIVE HALF-LIFE).

B.O.D.: Biochemical Oxygen Demand.

BONE SEEKER: Any compound or ion which migrates in the body preferentially into bone.

BOTTOM ANIMALS: Small macroscopic animals, such as aquatic insect larvae, snails, and worms that live on the river bottom on or under rocks and in sand or mud.

BOTTOM SAMPLE: A quantitative collection of bottom animals taken from a specified area of river bottom.

CARRIER: (a) A quantity of an element which may be mixed with radioactive isotopes of that element giving a ponderable quantity to facilitate chemical operations. (b) A substance in ponderable amount which when associated with a trace of another substance will carry the trace with it through a chemical or physical process, especially a precipitation process. If the added substance is a different element from the trace, the carrier is called a non-isotopic carrier.

C.F.S.: Cubic feet per second.

COINCIDENCE: The occurrence of ionizing events in one or more detectors simultaneously or within an assignable time interval, as a result of the passage of a single particle or of several generically related particles.

COINCIDENCE CORRECTION: Mathematical calculation to correct observed count to the count free of coincidence losses.

COLIFORM OR COLIFORM GROUP: Those organisms which will ferment lactose in the presence of brilliant green bile in the proportions contained in standard dehydrated media of that type.

CONTAMINATION, RADIOACTIVE: Deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence may be harmful. The harm may be in vitiating the validity of an experiment or a procedure or in actually being a source of danger to personnel.

COSMIC RAYS: Radiation that has its origin outside of the earth's atmosphere and is capable of producing ionizing events in passing through air or other matter.

COUNT (Radiation Measurements): The external indication of a device designed to enumerate ionizing events. It may refer to a single detected event or to the total registered in a given period of time. The term often is erroneously used to designate a disintegration or ionizing event.

C.P.M.: Counts per minute.

CURIE (c): That quantity of a radioactive material having associated with it 3.7×10^{10} disintegrations per second.

DECAY CURVE: A curve showing the relative amount of radioactive substance remaining after any time interval.

DECAY, RADIOACTIVE: The decrease, with time, of the number of radioactive atoms in a sample as a result of their spontaneous transformation. The term is also used as a synonym for "radioactive disintegration".

DIATOMS: Microscopic unicellular algae having siliceous cell walls.

DISINTEGRATION CONSTANT: The fraction of the number of atoms of a radioactive isotope which decay in unit time; "λ" in the equation $N = N_0 e^{-\lambda t}$, where N_0 is the initial number of atoms present, and N is the number of atoms present after some time, t.

ECOLOGY: The relationship of aquatic organisms to their environment and the interrelationships between these organisms.

EFFECTIVE HALF-LIFE: Time required for a radioactive element fixed in an organ or the tissues of an animal body to be diminished 50 per cent as a result of the combined action of radioactive decay and biological elimination.

$$\text{Effective half-life} = \frac{\text{Biological half-life} \times \text{Radioactive half-life}}{\text{Biological half-life} + \text{Radioactive half-life}}$$

EFFICIENCY (Counters): A measure of the probability that a count will be recorded when radiation is incident on a detector. Usage varies considerably so that it is well to make sure which factors (window transmission, sensitive volume, energy dependence, etc.) are included in a given case.

FILAMENTOUS OR ATTACHED ALGAE: Long filaments or masses of algae attached to rocks, logs, or other objects in the river and remaining in one position.

FISH, ADULT (As used for these studies): Fish weighing more than 10 grams each and usually sexually mature. This may also include the young of the large species.

FISH, JUVENILE (As used for these studies): Small fish, usually young-of-the-year, weighing less than 10 grams each. This may also include the adults of very small species such as dace.

GAS FLOW COUNTER (Radiation): A counter in which an appropriate atmosphere is maintained in the counter tube by allowing a suitable gas to flow slowly through the sensitive volume.

GEIGER-MULLER (G-M) COUNTER: By popular usage, a Geiger-Muller counter tube together with its associated electronic equipment.

GEIGER-MULLER (G-M) TUBE: A gas-filled chamber, usually consisting of a hollow cylindrical cathode and a fine wire anode along its axis. The operating voltage is of such magnitude that a discharge triggered by a primary ionizing current will spread over the entire anode until stopped by the reduction of the field by space charge.

GENERIC COMPOSITION: Classification of organisms into groups such as class, order, or genera.

GEOMETRY FACTOR (Radiation): The average solid angle at the source subtended by the aperture or sensitive volume of the detector, divided by the complete solid angle (4π). Frequently used loosely to denote counting yield or counting efficiency.

HALF-LIFE, RADIOACTIVE: Time required for a radioactive substance to lose 50% of its activity by decay.

INDUCED RADIOACTIVITY: That radioactivity produced in a substance by bombardment with neutrons or other particles.

ION: Atomic particle, atom, or chemical radical bearing an electrical charge, either negative or positive.

IONIZING RADIATION: Any radiation capable of producing ions in its passage through matter.

ISOTOPE: One of several different nuclides having the same number of protons in their nuclei, and hence having the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Almost identical chemical properties exist between isotopes of a particular element.

METABOLISM: The sum of all the physical and chemical processes by which living organized substance is produced and maintained and by which energy is made available for the uses of the organism.

MONITORING: Periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in an occupied region, as a safety measure for purposes of health protection.

M.P.C.: Maximum permissible concentration.

M.P.N. or M.P.N. INDEX: The number of coliform organisms per 100 ml. when calculated from multiple tube dilution tests.

NEUTRON: Elementary nuclear particle with a mass approximately the same as that of a hydrogen atom and electrically neutral; its rest mass is 1.00893 mass units.

NUCLEAR FISSION: A nuclear transformation characterized by the splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy.

NUCLEAR REACTOR: An apparatus in which nuclear fission may be sustained in a self-supporting chain reaction. The usual components of a nuclear reactor are as follows: 1) fissionable material (fuel) such as uranium or plutonium, 2) moderating material (unless it is a fast reactor), 3) usually a reflector to conserve escaping neutrons, 4) provision for heat removal, and 5) measuring and control elements. The terms "pile" and "reactor" have been used interchangeably.

NUCLEUS (Of an Atom): That part of an atom in which most of the mass and the total positive electric charge are concentrated.

OPERATING VOLTAGE: As applied to radiation detection instruments; voltage across the electrodes in the detecting chamber required for proper detection of an ionizing event.

ORGAN: Organized group of tissues having one or more definite functions to perform in an animal body.

PERMISSIBLE DOSE: The amount of radiation which may be received by an individual within a specified period with expectation of no harmful result to himself. For long-continued X- or gamma ray exposure of the whole body it is 0.3 r per week measured in air.

PHYTOPLANKTON: Planktonic plant life.

PILE: (See NUCLEAR REACTOR).

PLATEAU: As applied to radiation detector chambers, the level portion of the counting rate-voltage curve where changes in operating voltage introduce minimum changes in the counting rate.

P.P.M.: Parts per million.

PLANKTON: Free floating microscopic plant and animal life suspended in water and subject to river currents and to wind and wave action.

PLANKTON NET (As used for these studies): A fine meshed bolting silk net that can be towed through the water to collect plankton organisms. The standard number 20 net has 173 meshes per inch.

PROPORTIONAL COUNTER: An instrument having a gas filled radiation detection tube in which the pulse produced is proportional to the number of ions formed in the gas by the primary ionizing particle.

RADIOACTIVITY: Process whereby certain nuclides undergo spontaneous disintegration in which energy is liberated, generally resulting in the formation of new nuclides. The process is accompanied by the emission of one or more types of radiation, such as alpha particles, beta particles, and gamma photons. The property of radioactivity is exhibited by more than fifty naturally occurring isotopes (natural radionuclides) and is commonly referred to as natural radioactivity. The property of radioactivity can be induced in certain elements under controlled conditions and in such instances the resultant radioactivity is referred to as artificial radioactivity.

SCALER: An electronic device that produces an output pulse whenever a prescribed number of input pulses have been received.

SCATTERING: Change of direction of sub-atomic particle or photon as a result of a collision or interaction.

SEDGWICK-RAFTER CELLS: A small cell, arranged as a glass slide, for counting plankton organisms. The cell usually has a liquid capacity of 1 milliliter.

SELF-ABSORPTION: Absorption of radiation emitted by radioactive atoms by the matter in which the atoms are located; in particular, the absorption of radiation within a sample being assayed.

SURBER BOTTOM SAMPLER: A sampler used in shallow riffle areas for collecting bottom samples from a specified area of river bottom. The sampler consists of a metal frame, for marking one square foot of river bottom, and a net into which the animals are washed when brushed free from bottom materials.

TRACER, ISOTOPIC: The isotope or non-natural mixture of isotopes of an element which may be incorporated into a sample to make possible observations of the course of that element, alone or in combination, through a chemical, biological, or physical process. The observations may be made by measurement of radioactivity or of isotopic abundance.

ZOOPLANKTON: Planktonic animal life.

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APPENDIX "A"

ANALYTICAL AND RADIOLOGICAL COUNTING METHODS

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FOREWORD

The laboratory methods used during the Columbia River Studies were taken from many sources. While several of these, commonly accepted as standard, have been used without modification, others have of necessity been adapted to the conditions found in the Columbia River.

All of the analyses performed during the studies, whether made routinely or periodically, are included in this presentation. Where the method is taken from a commonly accepted source only the reference is given. In other cases, however, the method is given in detail. References will be found at the end of this appendix.

The analyses are grouped under the general headings of chemical, bacteriological, biological, gross beta radioactivity, and alpha radioactivity in order to provide facility of reference.

As yet no standard procedures have been developed for the radiological examination of water samples and biological specimens. The methods outlined below are based on methods in use by the General Electric Company's Radiological Sciences Department, at Hanford Works, and the Sanitary Engineering Center, with some modification for purposes of the Columbia River Studies.

CHEMICAL AND PHYSICAL EXAMINATIONS

TEMPERATURE

The temperature of the sample was taken at the time of collection and expressed in degrees Centigrade, to the nearest half-degree. A Weston "all-metal" thermometer was used.

TURBIDITY

Turbidity measurements were made with commercial turbidimeters, as follows:

1. Hellige Turbidimeter, Model 8000. The apparatus is based on the comparison of a beam of light with the Tyndall effect produced from the lateral illumination of the specimen by the same light source. Determinations were made in accordance with directions furnished with the instrument. This method was used on water samples collected for chemical analysis, with the determinations being made in the laboratory.

2. U.S.G.S. Standard Water Turbidity Scale. This consists of a weighted Bakelite Strip, 8 inches long, calibrated from 50 to 3,000 parts per million. Attached to the upper end is a tape 4 feet long, calibrated from 7 to 45, and at the lower end is a platinum needle. The strip is immersed vertically until the platinum needle just disappears when viewed from a fixed point near the upper end of the tape. The depth of immersion as shown by the scale markings indicates the turbidity in parts per million. This method was used to determine turbidities in the field at the site and time of taking biological samples.

HYDROGEN-ION CONCENTRATION - (pH)

Two types of instruments were used for this examination:

1. Beckman pH Meter, Model H-2. Determinations were made after the samples had been brought to the laboratory, according to instructions furnished with the instrument.

2. Hellige Pocket Comparator. This instrument was used for determining the pH in the field at the time and site of collection of biological specimens, in accordance with the directions furnished with the instrument.

ALKALINITY

1. Methyl Orange. "Standard Methods." (1)

2. Phenolphthalein "Standard Methods."

AMMONIA NITROGEN

"Standard Methods."

ORGANIC NITROGEN

"Standard Methods."

NITRITE NITROGEN

"Standard Methods."

NITRATE NITROGEN

"Standard Methods."

CHLORIDES

"Standard Methods."

DISSOLVED OXYGEN

Determination was made by the Winkler Method, as given in "Standard Methods".

BIOCHEMICAL OXYGEN DEMAND

"Standard Methods."

CALCIUM (1)

Ammonium oxalate precipitates calcium quantitatively as calcium oxalate, which is then dissolved in sulfuric acid and titrated with standard potassium permanganate.

Some modification of the "Standard Methods" procedure was necessary in order to remove a few interfering substances that are assumed to be absent when using that procedure.

Reagents

1. Hydrochloric acid, 1:1
2. Ammonium hydroxide, 1:1
3. Ammonium hydroxide, 1:100

4. Ammonium oxalate solution. Saturated solution of $(NH_4)_2C_2O_4 \cdot H_2O$ at room temperature.

5. Methyl red indicator solution

6. Potassium permanganate, 0.1N $KMnO_4$

7. Sulfuric acid, 1:8

Procedure

1. Add 2 ml. HCl to a 500-ml. sample and evaporate to about 30 ml.

2. Filter hot through a Whatman #40 filter paper. Wash the beaker repeatedly with small portions of hot distilled water until perfectly clean, filtering the washings.

3. Heat the filtrate, which should have a volume of approximately 200 ml., to boiling and make just alkaline to methyl red with 1:1 NH_4OH.

4. Add about 0.5 ml. in excess, stir and boil gently for about 3 minutes. If iron or aluminum are precipitated then filter through a Whatman #41 filter paper, washing the precipitate 10 times with hot water.

5. Make the filtrate acid with 1:1 HCl and heat to boiling.

6. Slowly add 10 ml. hot ammonium oxalate (80° - 90°C).

7. Add 1:1 NH_4OH until the solution is alkaline, then 1 ml. in excess.

8. Digest the precipitate 1 to 2 hours at 80° - 90°C.

9. Filter and wash the precipitate 10 times with 1:100 NH_4OH. (Save the filtrate for sulfate determination, if this is to be made.)

10. Carefully transfer the filter paper containing the precipitate to a 500-ml. Erlenmeyer flask. Add 25 ml. hot 1:8 H_2SO_4 and 100 ml. hot distilled water.

11. Titrate slowly with 0.1N $KMnO_4$ to a faint pink end-point.

Calculation of Results

$$\text{p.p.m. Calcium} = \frac{\text{ml. of } 0.1\text{N } KMnO_4 \times 2{,}000}{\text{ml. of sample}}$$

IRON (ORTHO-PHENANTHROLINE METHOD) (1)

Ortho-phenanthroline reacts with ferrous iron at a pH of 8.0 to 9.0 to give a maximum depth of color. The color is fairly stable.

Some modification of the "Standard Methods" procedure was necessary in order to remove a few interfering substances that are assumed to be absent when using that procedure.

Reagents

1. Ortho-phenanthroline solution. Dissolve 0.12 g. of Ortho-phenanthroline monohydrate in 100 ml. distilled water. Two ml. are required for each 0.1 mg. of iron.

2. Hydroxylamine solution. Dissolve 10 g. hydroxylamine hydrochloride in 100 ml. distilled water.

3. Hydrochloric acid, C.P. Conc. free from iron.

4. Ammonium hydroxide, C.P. Conc.

5. Standard iron solution. Dissolve 0.7022 g. $FeSO_4(NH_4)_2SO_4 \cdot 6H_2O$, C.P. in 50 ml. distilled water and 20 ml. H_2SO_4. Dilute to 1 liter. One ml. is equal to 0.1 mg. iron.

Procedure

1. To a 100-ml. sample add 1 ml. conc. HCl and concentrate to about 25 ml. by boiling. (Amount of sample used depends upon the iron content.)

2. Cool to room temperature and clarify if necessary by filtering or centrifuging.

3. Add 1 ml. hydroxylamine and 2 ml. O-phenanthroline solution.

4. Adjust pH to between 8.0 and 9.0 with a few drops of NH_4OH.

5. Bring the volume up to 50 ml. with distilled water and read on the photelometer, using a 50 mm. cell and a green filter.

A blank should be run to allow correction for iron in the reagents. Results are obtained by comparison with a standard curve prepared from a series of dilutions of the standard iron solution.

Calculation of Results

$$\text{p.p.m. Iron} = \frac{\text{mg. (from curve)} \times 1{,}000}{\text{ml. sample}}$$

ZINC (2)

Dithizone produces a dark violet color with zinc, suitable for colorimetric measurement. Addition of sodium thiosulphate as a complex-forming agent, to tie up interfering metals, after adjusting the pH to about 4.75, makes the method selective for zinc. Great care must be exercised to prevent contamination of reagents and apparatus.

Reagents

1. Redistilled water, stored in a polyethylene bottle.

2. Dithizone solution, 0.1 g. in 1 liter carbon tetrachloride.

3. Dithizone solution, 0.001%. Dilute 100 ml. of 0.01% solution to 1 liter with carbon tetrachloride.

4. Acetate buffer. Mix equal volumes of 2N sodium acetate and 2N acetic acid. Remove possible metal contamination by shaking with several portions of 0.01% dithizone, until final extract remains green.

5. Sodium thiosulphate. Dissolve 25 g. $Na_2S_2O_2 \cdot 5H_2O$ in 100 ml. redistilled water.

6. Nitric acid, 1:1

7. Hydrochloric acid, 1:1

8. Standard zinc solution, 0.01% in about 0.1N hydrochloric acid. Reagent grade 30-mesh zinc is dissolved in a slight excess of hydrochloric acid and diluted to volume. From this solution a 0.001% solution is prepared by dilution in 0.01N to 0.02N hydrochloric acid.

Procedure

1. Wash all glassware with nitric acid and rinse repeatedly with redistilled water.

2. To 10 ml. of sample in a 125-ml. separatory funnel add 1 drop of 1:1 hydrochloric acid and 5 ml. acetate buffer.

3. Mix thoroughly and add 1 ml. sodium thiosulphate solution with mixing.

4. Extract with two 5-ml. portions of 0.001% dithizone.

5. Adjust photelometer to 100 reading with 0.001% dithizone, and read the treated sample in a 10-mm. covered cell. A 530 mμ filter is suitable.

6. Compare readings with a standard curve prepared from a standard zinc solution.

Calculation of Results

$$\text{p.p.m.} = \frac{\text{mg. (from curve)} \times 1{,}000}{\text{ml. of sample}}$$

COPPER (2)

The colorimetric determination of copper by addition of diethyldithiocarbamate followed by extraction from the aqueous phase with carbon tetrachloride can be carried out successfully on highly turbid samples. At a pH of 9.0 to 9.6 for the aqueous phase, in the presence of ammonium citrate, iron and manganese do not interfere.

Reagents

1. Ammonium citrate, 20 g. per 100 ml.
2. Sodium diethyldithiocarbamate, 0.1% aqueous solution.
3. Carbon tetrachloride, C.P.
4. Ammonium hydroxide, C.P. Conc.
5. Hydrochloric acid, C.P. Conc.

Procedure

1. Add 3 or 4 drops conc. HCl to 500 ml. of sample and evaporate to about 25 ml.
2. Transfer to a 125-ml. separatory funnel and make up to 50 ml. with washings.
3. Add 5 ml. ammonium citrate and mix thoroughly.
4. Add 2 ml. conc. ammonium hydroxide with mixing.
5. Add 1 ml. sodium diethyldithiocarbamate, mix well and allow to stand 60 seconds.
6. Extract with two 5-ml. portions of carbon tetrachloride.
7. Place extracts in 10-mm. covered cell and read on the photelometer, using a blue filter.

A blank is prepared by treating copper-free water in the same manner as the sample.

Calculation of Results

Results are calculated by comparison with a curve made by treating solutions of copper sulfate in the manner described above, making correction for the blank reading if necessary.

$$\text{p.p.m. Copper} = \frac{\text{mg. (from curve)} \times 1{,}000}{\text{volume of sample}}$$

SULFATES

During the early period of the work sulfates were determined by the method outlined in the instruction sheets furnished with the Hellige Turbidimeter, Model 8000, and from the curves supplied with the instrument. The use of the turbidimeter for determining sulfates was discontinued on May 26, 1952. All subsequent determinations were made gravimetrically according to "Standard Methods". Analyses were generally made on the filtrate from the calcium determination, acidified before heating and adding the barium chloride solution.

MAGNESIUM

"Standard Methods."

MANGANESE

"Standard Methods."

PHOSPHATES

"Standard Methods."

TOTAL SOLIDS

"Standard Methods."

BACTERIOLOGICAL EXAMINATIONS

Bacteriological Examinations were made in accordance with the procedure outlined in "Standard Methods". Three tubes in each of 3 dilutions (usually 1.0, 0.1, and 0.01 ml.) were planted and incubated for 24 to 48 hours for the presumptive test. Samples showing gas formation were transplanted to brilliant green bile broth for confirmation.

BIOLOGICAL EXAMINATIONS

Modifications of various methods and their application to the particular conditions in the waters involved are discussed in this section. Specific details of these methods can be found in the Bibliography, at the end of this appendix.

PLANKTON (3) (4) (5) (6) (7)

The determination for plankton included collecting plankton-bearing water, concentrating the organisms by means of a centrifuge or fine net and analyzing the concentrate. Collection methods used for quantitative samples differed from those used for radiological samples.

Collection of Samples

Because of river currents and rapids generally prevalent, the plankton was uniformly distributed from surface to bottom. Hence, samples were taken at or just below the surface at each range. About 1 liter of water was taken from each of 15 to 20 points between shores, as the boat traveled slowly across the stream, and composited in a 5-gallon milk can. Where fewer points were sampled at a cross-section enough sample was taken at each point to give a final quantity of about 5 gallons after compositing.

In impoundments or other areas where there was little or no current or uniform mixing of the water, samples were collected with a 3-liter Kemmerer sampler. Normally a sample was taken at the surface and at several other depths. The composite sample, whether surface or depth, was made up from water collected at these points. Approximately 5-gallon samples were obtained.

If the elapsed time between collection and laboratory examination was to be over 4 hours the samples were preserved by enough formalin to make a 5% solution.

Laboratory Examinations

After thorough mixing, 2 to 6 liters of the composite sample, depending upon the expected plankton density, were withdrawn and concentrated in a Foerst centrifuge. Two liters were found to be adequate for most Columbia River samples. The concentrate was then made up to a definite volume, normally 10 to 20 ml, with distilled water and counted. Where plankton were very abundant or much silt was present the concentrate was made up to 40 or 80 ml. One milliliter was measured into a Sedgwick-Rafter counting cell, placed under a microscope, and the "survey" and "differential" counts made. A previously calibrated Whipple ocular micrometer was used with the microscope.

In the "survey" count the whole cell was scanned at low power, usually at 100X magnification, and the number of the larger organisms, mostly zooplankters, was counted. These included microcrustaceans, rotifers and protozoans. Some of the more abundant of these were identified to genus. The results were expressed in organisms per liter.

The "differential" count included all microorganisms that were apparently alive at the time of collection, exclusive of debris, case skins, fragments or skeletal structures. Each cell, filament or colony was counted as one plankter

and each kind of plankter was counted separately. Separation was to class and to genus when identification was feasible. The counts were kept separately by means of mechanical tallies. Counts were taken in 10 fields, the necessary calculations made and the results expressed in number per milliliter. Practically all of the organisms in the differential count were phytoplankters.

A 10-liter sample of water was removed from the original 5-gallon container and run through a Foerst centrifuge for determining plankton weights. The concentrate was washed into a tared porcelain boat and placed in an electric oven at 60°C. for approximately 24 hours. The sample was next weighed, and the results reported as wet weight of plankton in milligrams per liter.

The same sample was then placed in an electric furnace at 600°C. and allowed to remain for 30 minutes. It was weighed and the difference between this weight and the wet weight used to calculate the organic weight or loss on ignition, in milligrams per liter.

There were certain inaccuracies in this method of obtaining plankton weights, especially during high water periods when the water was turbid. As silt and fine sand are not easily removed from the plankton concentrate, these materials were included in the plankton weights. The weights during such periods would not accurately reflect the amount of plankton. However, during periods of normal flow very little silt was suspended in the water and reasonably accurate values for plankton were obtained.

Radiological Samples

It was not considered feasible to use the above methods for collecting and concentrating samples for radiological analyses. The size of sample collected was considered too small for reasonably accurate results. For larger samples, too much time would be required to run the large quantities of water through the small-capacity Foerst centrifuge. The method might be feasible if a large capacity, highspeed centrifuge were available. Hence, tow nets were used for obtaining samples for radioactivity counting.

A standard No. 20 plankton net, having 173 meshes per inch, was towed by boat back and forth across a range until an adequate sample was obtained. This ordinarily required from 10 to 30 minutes, depending upon the amount of plankton present. It was desirable to obtain from one-half to one gram wet weight of plankton from each tow. The concentrate was washed from the net into a small bottle, formalin added for preserving, if necessary, and taken to the laboratory. If the sample contained a large amount of silt or fine sand, the plankton was separated by shaking and decanting off the lighter portion which included most of of the plankton.

The laboratory preparation of samples for radiological counting is given in the section on radiological examinations. The weights on which plankton radioactivity counts are based are similar to and may be compared directly with wet weights obtained by the quantitative method.

FILAMENTOUS ALGAE (3) (4) (5) (6) (7)

The term filamentous algae as used in this report denotes sedentary

or attached forms of principally green algae that occur in masses and are usually growing on, or attached to objects on the river bottom.

While no quantitative determinations were made, samples were taken for radiological counting. Collections were made by scraping from rocks, logs or other objects and washing free of silt, sand and debris. The principal forms were identified to genus, blotted free of surface moisture and approximately two-gram samples prepared for radiological examination.

BOTTOM ANIMALS (3) (5) (8) (9) (10)

Bottom animals include those bottom dwelling animals, mostly macroscopic in size, that live on the bottom of rivers and lakes either on or under rocks or in sand, mud and aquatic vegetation. Prevalent types in the Columbia River were insect larvae (such as midgeflies, caddisflies and mayflies), snails, crayfish and various worms.

Collection of Samples

Two different sampling methods were used in this survey depending, on the type of area sampled. Samples in fast moving, rocky-bottomed rivers were taken in riffles with a Surber square-foot sampler. Those in slow-moving waters, such as impoundments with sand or mud bottoms, were taken with an Ekman dredge.

The Surber sampler is best used in waters having a depth of 2 feet or less, a very rapid current, and a river bottom covered with coarse gravel or rubble less than 6 inches in diameter. River stages should be such that the areas to be sampled are stable and are covered with water at all times. Sampling locations for this project were generally in riffle areas near the shore and in a few cases, at the edges of islands farther out in the stream.

Because of the large fluctuation in river stages during the spring runoff, samples could not be taken during April, May, June, and July. Care had to be taken at other seasons to be sure a stable bottom was present.

Considering the various factors mentioned above, the Surber sampler was considered best for the Columbia River and tributaries in the Priest Rapids - Paterson Section. The swift currents and rocky bottoms precluded the use of other types, such as the Ekman or Peterson dredges.

In collecting samples, the Surber sampler was placed on the bottom of the river in a selected area and normally in 12 to 18 inches of water. All of the organisms were brushed from the loose rocks and river bottom, down to hardpan, in the area within the square foot marker. The organisms thus removed were washed by the current into the net below the framework. Using metal screens 30- to 40-mesh, and flat enamel pans most of the sand and rocks and some of the debris were separated from the sample and the organisms placed in a sample bottle.

Three 1-square foot areas taken in the same general location were composited to make up one sample. Formalin was added to make an approximately 10% solution, and the samples taken to the laboratory.

In areas with soft bottoms and slow currents, such as Roosevelt Lake and Bonneville Reservoir, samples were collected by lowering an Ekman Dredge (usually 1/4 square foot) to the bottom, tripping the release mechanism and bringing the silt, sand and organisms to the surface, where the contents were discharged into a pail. The sample was washed on a large circular 30-mesh screen to remove most of the mud and fine sand. The residue was then placed in a glass jar, preserved with formalin and taken to the laboratory. Four samples were generally taken at each range, one near each shore and one at each of the quarter points.

Laboratory Examinations

In the laboratory, the samples were further cleaned of debris and the animals manually picked out and separated into groups, generally to order. In a few cases further identifications were made. The animals in each group were then counted and weighed, after blotting free of moisture, and reported as number and weight in grams per square foot. Crayfish were not included in the quantitative estimation.

Radiological Samples

Bottom animal samples for radiological purposes were generally confined to those groups in which individual organisms were fairly large, abundant and easily collected. Animals such as caddisfly larvae, snails and crayfish were most frequently used. A few samples of midgefly larvae, mayfly nymphs and other aquatic insects were also collected. Collections were made either by picking directly from rocks or by holding a piece of screen or a small minnow seine in a riffle area, disturbing the rocks and picking the washed off animals from the seine. The samples were preserved in formalin, taken to the laboratory, and prepared for radiological counting.

FISH (11) (12) (13) (14) (15) (16)

For the purposes of this study juvenile fish included small fish, generally weighing less than 10 grams and mostly young-of-the-year. Adults of small species, such as dace or sticklebacks, were also included in this category. Adult fish generally included those specimens weighing over 10 grams and in most cases sexually mature. However, the young of some large-sized species were also included.

Juvenile Fish

Small fish or juveniles were collected by using a 6-, 10- or 20-foot 1/4-inch mesh minnow seine, usually near the shore and in shallow water at each range. In order to get as wide a variety of species as possible seining was done in several types of areas. Locations included those near piles of brush and tumble weeds, in flooded areas, where weeds and willows were partially submerged, and under rocks in riffle areas. During the summer and fall seasons fish were quite plentiful and could be observed and taken from many open water areas. In the winter, however, practically all species were under cover and the areas from which they could be taken were quite limited. At such times tumble weeds were placed in the water and weighted down with rocks to serve as areas for fish concentration.

Care had to be used in collecting samples for radiological determinations. Schools of fish could be found in small pools near the edge of the river and in sloughs, but such collections contained much less activity then specimens from the main river. Thus, samples for radiological purposes were taken whenever possible in main river channels. The relative abundance of all species taken at any one range was noted, regardless of the type of collecting area.

Not all of the specimens were saved, but only representatives of each species. These were placed in sample bottles, preserved with 10% formalin, and taken to the laboratory. The species were then separated and, where possible, three samples of each species prepared for radiological counting. An effort was made to have each sample consist of fish of fairly uniform size, the three samples covering a range of sizes. Samples which contained more than 1 fish were usually limited to approximately 2 grams each, but individual fish to a maximum of 10 grams were used. The total length of each specimen was recorded, the fish blotted free of surface moisture and each sample weighed to the nearest 0.01 gram before processing for radioactivity measurement.

Adult Fish

Adult fish were collected primarily with 1-inch, 2-inch and 3-inch mesh gill nets, 25 or 50 yards long and 5 or 6 feet in depth. In most cases 3 nets, one of each size mesh, were tied together and sets made on the bottom of the river in water depths of from 10 to 30 feet. Some sets in impoundments were at depths up to 125 feet. Sets were made from a small boat using conventional weights and floats. The current in the Columbia River was too rapid to permit sets in the main river channel. Consequently most of them were made in somewhat protected areas with much less current, usually near the shore or near islands. The best catches were made when the nets were set across the current, but where the water was too swift it was impossible to place the nets in this manner. Very poor success was obtained when sets were made paralleling the current or the shore.

Overnight sets were made in all cases because, due to the very clear waters, daylight sets were very unproductive. The fish were removed from the nets and taken to the laboratory. The species, total length, weight, sex and maturity of each specimen was recorded for reporting results.

Three different sized individuals of each species were used for radiological preparation. Samples of various parts and organs including scales, bone, muscle, skin, testes, ovary, liver, kidney and stomach contents were taken from each fish. Approximately 1-gram samples of the dense parts such as scales and bone and 2-gram samples of the other parts were normally used. These parts were weighed into 50-ml beakers, to an accuracy of 0.01 gram, and then prepared for radiological examination.

BETA RADIOACTIVITY COUNTING

Radiological examinations were confined principally to determination of gross beta particle activity density. For water samples, results are expressed in terms of microcuries per milliliter. For fish and other biological specimens results are expressed in terms of microcuries per gram.

COLLECTION OF SAMPLES

The collection of samples for radiological counting was generally the same as those used for physical, chemical, and biological examinations. Those methods have already been discussed, along with necessary modifications for radiological samples, in preceding sections of this Appendix.

PREPARATION OF WATER SAMPLES

This procedure is not applicable for volatile materials such as iodine or for dissolved gases such as krypton, radon, carbon dioxide, etc. It is of questionable significance for isotopes which emit low energy beta particles, such as C^{14} and S^{35}, because of the large amount of self-absorption of the particles in the residue.

Reagents

1. 2N nitric acid, C.P.
2. Distilled water

Procedure

1. Pour 500 ml of the sample into a calibrated 600-ml beaker.
2. Wash the sample bottle with 10-15 ml concentrated nitric acid and add this to the sample.
3. Cover the beaker and allow to evaporate to a volume just sufficient to cover the bottom of the beaker. Evaporate slowly enough to avoid super-heating or bumping, which would cause spilling over the sides of the beaker.
4. Transfer the contents of the 600-ml beaker to a 50-ml beaker.
5. Wash the 600-ml beaker three times with 2N nitric acid, and add the washings to the 50-ml beaker.
6. Evaporate the contents of the 50-ml beaker to a small volume, and transfer to a 1-1/8-inch stainless steel counting dish by means of a medicine dropper.
7. Wash several times with 2N nitric acid to insure complete transfer of all the material in the beaker.

8. Evaporate to dryness in the counting plate and place in muffle furnace for about 1 minute at under 600°C.

9. Mount plate on a properly labeled card for counting.

If the weight of the residue is desired, weigh the counting plate both before and after addition of the sample.

Precautions and Limitations

1. Extreme care must be taken to prevent cross-contamination. If there are two relative levels of radioactivity in the various samples being prepared, separate utensils and preparation hoods are necessary for each level.

2. The sample must be completely dry, otherwise the activity count will be less than the true value. The muffle furnace will dry the residue to the point where it is not necessary to use a desiccator for transferring the sample to the counting instruments. The temperature in the muffle furnace must be held under 600°C. to avoid excessive volatilization of the sample.

3. Preparation of a single sample takes about 2 hours. However, 10 to 15 samples can be prepared simultaneously without too much detailed attention during the first hour of the procedure.

4. It is desirable to run a blank and a spiked sample with each set of samples.

PREPARATION OF PLANKTON SAMPLES

Reagents

None

Procedure

1. Filter the plankton concentrate through a No. 1 Whatman filter paper (8 cm.) in a Buchner funnel, using a vacuum pump.

2. Remove duplicate 0.2- to 0.5-gram portions of the residue from the filter paper and spread evenly on 1-inch stainless steel counting dishes.

3. Place the dishes containing the residue in an oven at 90 to 100°C. and dry for approximately 30 minutes, or until all surface moisture has been removed.

4. Cool the sample in a desiccator, weigh, and count directly. Most of the samples should contain between 0.10 and 0.50 grams of plankton after drying.

A digestion procedure similar to the one for filamentous algae was

used for some plankton samples. Since the plankton was mostly diatoms with siliceous shells and digestion did not appreciably reduce the volume of sample, the above procedure was used in most cases.

PREPARATION OF FILAMENTOUS ALGAE SAMPLES

Reagents

1. Nitric acid, C.P., Conc.
2. Distilled water

Procedure

1. Carefully wash sample to remove silt and foreign material. Remove excess moisture by pressing between blotter or filter paper.
2. Transfer approximately 2 grams of sample to a tared 50-ml beaker and weigh.
3. Add 10 ml of HNO_3 and boil until solution is yellow-brown.
4. Repeat step 3 with 5-ml portions of Conc. HNO_3, and heat on a hot plate at 150°C. until sample is completely digested but before samples are evaporated to dryness.
5. Transfer the digestate, with a medicine dropper, to a 1-inch stainless steel dish and evaporate to dryness on a hot plate.
6. Muffle counting dish to red heat.
7. Weigh and mount on card for counting.

PREPARATION OF BOTTOM ANIMAL SAMPLES

Reagents

1. Nitric acid, C.P., Conc.
2. Nitric acid, 2N, C.P.

Procedure

1. Press sample between blotter or filter paper to remove excess moisture.
2. Transfer a 1- to 2-gram portion to a tared 50-ml beaker and weigh.
3. Add 0.5 to 1 ml. of Conc. HNO_3 and heat on a hot plate at 150°C. until sample has digested and evaporated to dryness.

4. Transfer to a 600°C. muffle furnace for 5 to 10 minutes, leaving muffle door open.

5. Remove from furnace and cool.

6. Repeat steps 3 and 4 until sample is ashed completely (white or gray-white residue).

7. Using a medicine dropper, transfer residue to a tared 1-inch stainless steel counting dish with Conc. HNO_3. Final rinses of beaker are with 2N HNO_3.

8. Evaporate to dryness on a hot plate.

9. Muffle counting dish to red heat.

10. Weigh and mount on card for counting.

PREPARATION OF SAMPLES OF CRAYFISH AND SNAILS IN THE SHELL

Reagents

1. Hydrochloric acid, C.P., Conc.

2. 2N Nitric acid, C.P.

3. Distilled water.

Procedure

1. Determine weight of crayfish.

2. Place under infra-red lamp until dry. (About 1 hour).

3. Crush sample in a beaker.

4. Add about 10 ml concentrated HCl. Place under infra-red heater and dry. Add 1 ml Conc. HNO_3.

5. Place in muffle furnace heated to 600-650°C. Leave door open. Ash for 5 to 10 minutes. Remove, cool, add more HNO_3 and heat again until sample is completely ashed.

6. Transfer with HNO_3 to 1-inch stainless steel plate. Dry on hot plate.

7. Weigh and mount on card for counting.

PREPARATION OF FISH SAMPLES

Reagent

1. Nitric acid, C.P., Conc.

2. Distilled water.

Procedure

1. Determine and record wet weight of sample, to the nearest 0.01 gram.

2. Place in 30-ml beaker. Add 0.5 or 1 ml concentrated HNO_3.

3. Heat under infra-red lamp until sample has digested to dryness.

4. Transfer beaker and sample to muffle furnace heated to 600-650°C. Leave muffle door open. Heat for 5 to 10 minutes. Remove sample from furnace, cool and add 0.5 ml of HNO_3.

5. Repeat steps 3 and 4 until sample is ashed completely. (White or grey-white residue).

6. Transfer residue to a tared 1-inch stainless steel plate with concentrated HNO_3. Final rinse of beaker is with water.

7. Evaporate to dryness under infra-red lamp. Flame plate in Bunsen burner to red heat.

8. Weigh and mount on card for counting.

PREPARATION OF MUD SAMPLES

Reagents

1. Nitric acid, C.P., Conc.

2. 8N Nitric acid, C.P.

3. Distilled Water

Procedure

1. Mix mud thoroughly, pour into large watch glass cover and place in 108°C. oven until dry.

2. Pulverize dried mud with spatula.

3. Weigh out duplicate 20-gram portions and place in Erlenmeyer flasks.

4. Add 100 ml 8N HNO_3. Stopper flask and shake on shaker for 30 minutes.

5. Decant sample through a Whatman #42 (7 cm.) filter paper. Wash mud onto filter and rinse at least 4 times with 10 ml portions of 8N HNO_3.

6. Place filtrate in a 250-ml beaker, cover with watchglass and evaporate to dryness on slow heating hot plate.

7. When residue appears dry place beaker on a fast-heating hot plate and heat until there is no evidence of moisture.

8. Cool and dissolve residue with 8N HNO_3, evaporate to dryness on 1-inch stainless steel plate for beta determination.

GENERAL GROUP ANALYSIS FOR BETA PARTICLE EMITTERS (17) (18)

Reagents

1. 2N Nitric acid, C.P.
2. Hydrogen Peroxide
3. Hydrochloric acid, C.P., dil.
4. Ammonium hydroxide
5. Potassium iodide
6. Hydrogen sulfide
7. Ammonium chloride
8. Hydrofluoric acid
9. Boric acid
10. Ammonium acetate
11. Ammonium oxalate, $(NH_4)_2C_2O_4$

Procedure

1. Weigh sample. The weight will vary from 5 to 100 grams, depending upon the type of sample and the anticipated activity level.

2. Digest in HNO_3 and ash in a muffle furnace.

3. Dissolve ash in 2 to 4N HNO_3. Centrifuge off any insoluble residue and spread, dry, weigh and count. Determine the decay and absorption pattern for the insoluble portion.

4. Make dissolved ash solution up to a suitable volume.

5. Prepare several standard aliquots for total count. Determine the decay and absorption pattern on one of these.

6. Withdraw duplicate aliquots of suitable size for regular cation group analyses as given below.

7. Add 5 mg each of the following carriers: Cu^{+2}, As^{+5}, Fe^{+3}, La^{+3}, Zn^{+2}, Co^{+2}, PO_4^{-3}, Na^{+1}, Ca^{+2}, if necessary.

8. Evaporate to near dryness to remove excess nitrates.

9. Dissolve in dilute HCl. Add few drops of H_2O_2 and boil. Neutralize with NH_4OH. Add 0.5 ml Conc. HCl for each 10 ml of solution. Add 3 drops KI solution. Heat to boiling, bubble in H_2S gas for 1 minute. Cool and saturate with H_2S for 1 minute. Centrifuge. Wash precipitate with water. Precipitate contains Cu and As groups, solution contains others.

10. Separate Cu and As groups precipitate by dissolving in NH_4OH and bubbling in H_2S. Precipitate in Cu group. Wash with water, and plate for count. To the solution, make acid with HCl and bubble in H_2S if needed. Precipitate is the As group. Wash with water, and plate for counting.

11. Evaporate the solution, left from step 9, to dryness with HNO_3 at least 3 times to remove all chloride. Dissolve in 8N HNO_3. Add 35 mg metallic tin. Digest in water bath with stirring till all tin is reacted. Digest about 10 minutes more. Centrifuge and wash. Repeat the above on the solution from the addition of tin on. Combine both precipitates for counting. Activity will be the PO_4 ion which comes down on the stannic acid precipitate.

12. Evaporate the solution from step 11 to almost dryness to remove excess nitrate. Add HCl and boil. Add 1.5 gms NH_4Cl powder per 10 ml. of solution. Make basic with NH_4OH. Digest few minutes on hot plate. Centrifuge and wash with hot water. The precipitate contains the Fe and Rare Earths group. Save the solution for remaining groups.

13. Separate Fe and Rare Earths groups by dissolving precipitate in 2N HNO_3. Transfer to lusterloid tubes. Make solution 4 normal in HF. Centrifuge and wash the Rare Earth precipitate that forms with dil. HF-HNO_3 solution. The solution will contain the Fe group. Dissolve the Rare Earths precipitate with Conc. HNO_3 - saturated H_3BO_3 solution, in the ratio of 1 to 2. Re-precipitate with NH_4OH. Wash precipitate with water, plate and count for Rare Earths group.

14. Make the Fe group solution basic with NH_4OH. Centrifuge the precipitate that forms with water. Plate and count for Fe group.

15. To the remaining solution from step 12, bubble in H_2S gas. Centrifuge and wash precipitate of Zn and Co groups which form with water. Save solution for next groups.

16. To divide the Zn-Co group, dissolve precipitate in HCl-HNO_3 mixture. Evaporate to dryness. Dissolve in 1 ml 2N $NaHSO_4$ and 2 mls of sat. Na_2SO_4. Add 10 drops of 3M $NH_4C_2H_3O_2$.

Bubble in H_2S. Warm to near boiling. Centrifuge, wash and plate the Zn group precipitate that forms. To the solution containing the Co solution, add few drops of bromine water and boil. Make basic with NH_4OH. Bubble in H_2S. Centrifuge, wash and plate the Co group precipitate that forms.

17. To the remaining solution from step 15, evaporate to dryness and heat to remove NH_4Cl and H_2S. Cool and dissolve in HCl. Make basic with NH_4OH in slight excess. Heat gently, and slowly add excess saturated $(NH_4)_2C_2O_4$. Centrifuge and wash Ca group precipitate that forms. Save solution.

18. Evaporate to dryness and count the solution from step 17. This is the soluble ion group.

COUNTING EQUIPMENT

Two types of counters were considered for routine beta activity determinations, the internal flow counter and the end-window Geiger-Muller tube counter. On the basis of the large sample load, the levels of activity found, and the previous experience of General Electric Company the latter type was selected for general use.

Beta particles are electrons which are emitted at high speeds from nuclei. The particles emitted from any one radioisotope do not have discrete energy values but have all energy values from nearly 0 to a maximum value. In comparison to the heavy alpha particles, beta particles have a much lower specific ionization, forming only 50 to 100 ion pairs per centimeter of path in air. Since much less of its energy is dissipated in ionization per unit distance, a beta particle has much greater penetrating power. Therefore, it is generally possible to measure this type activity with the Geiger-Muller counter.

The end-window G-M tube used consisted of a conducting cylinder cemented to a glass top, with a thin tungsten wire down the axis of the cylinder and a mica window over the end. The mica window was 1.8 to 2 mg/cm^2 thick and was thus able to screen out most alpha particles, while allowing most beta particles to pass through. The tube was filled with a special gas mixture under several centimeters of mercury pressure.

The tube was mounted in a lead shield designed to reduce cosmic and stray radiation as well as to exclude light, since the tube is somewhat photosensitive. This shielding, using about 2 inches of lead, cut the background to about 20 to 25 counts per minute. The shield was generally lined with aluminum and the sample mount was made of a similar light material, to reduce the scattering effect.

To operate the counter, a large positive voltage was applied to the center wire. The operating voltage for a particular tube was determined by counting a long half-life radioactive source in a fixed position at various voltages and making a plot of counting rate versus voltage.

The flat part of the curve is referred to as the plateau. In order to

minimize the effect of fluctuations in electrical power supply it is best to operate at the voltage shown by a point lying about one-third of the way across the plateau.

Instruments

Each end-window Geiger-Muller counting unit consisted of:

1 Ea. Geiger-Muller Tube, with end mica-window of approximately 1.8 mg/cm^2 (Tracerlab TGC-2, or equal).

1 Ea. Tube Mount, designed to hold mounting cards with samples at known fixed distances from the tube face. The distances, in inches, are 0.191 (most frequently used), 0.816, 1.441, 2.066, and 2.691. The mounts were designed and fabricated by General Electric Company locally. A diagram of the mount is shown in figure A-1.

1 Ea. Vertical Lead Shield, with 2-inch walls, to hold the tube and mount (Technical Associates Model LS-6, or equal).

1 Ea. Beta Gamma Scaling Unit (Nuclear Instrument and Chemical Corporation Model 161 or 163, or equal). For this study the counts were fed into a scale of 64.

1 Ea. Timer (Nuclear Instrument and Chemical Corporation Model T-1, or equal).

1 Ea. Register (Atomic Instrument Company Model 1238-B, or equal). A register is required when the Model 161, or equivalent scaling unit not equipped with a register, is used.

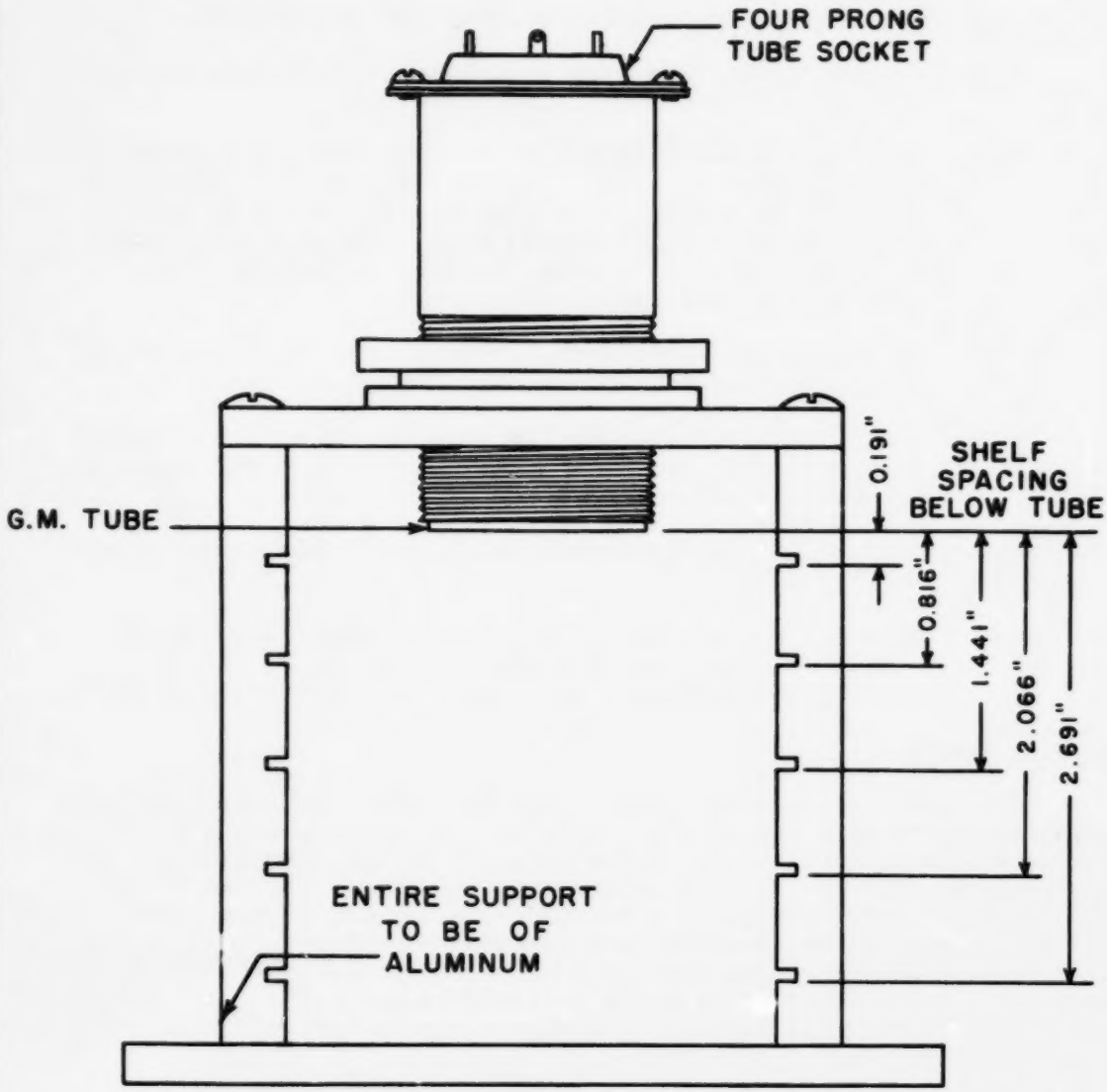
Counting Plates

The design of counting plates for low level work had been thoroughly studied by the Control Unit, Biophysics Section at Hanford Atomic Products Operation, and several factors considered in the design. For example, the plate must be dish-like, in order to hold relatively large volumes and speed up the evaporation; the corners of the dish must be such as to minimize the tendency for material to concentrate around the edge, thus influencing the geometry; the dish material must be uniform, smooth, stiff and lipped or flanged to permit centering below the G-M tube in exactly the same position each time it is placed in a standard cardboard mount; and it should be relatively inexpensive and easy to make.

With these factors in mind the plate chosen for beta counting was made from stainless steel 0.005 inch thick, 1-1/8-inches extreme lip diameter, 1/8-inch lip for seating the plate in the mounting card, 7/8-inch across the bottom of the dish, and 1/8-inch deep with a 1- to 2-ml capacity.

RELIABILITY OF INSTRUMENTS

In order to assure reliability of results the instruments were tested



SECTION OF THE

END-MICA-WINDOW, G.M. TUBE SUPPORT AND SHELF ASSEMBLY

Figure A-1

daily for counter response. This consisted essentially of setting up a control chart using a given source to determine that the counter stayed within certain statistical limits.

A new instrument, or one which had been out of service for one reason or another, after determination of the proper operating voltage and an overnight determination of background, was ready for the control chart run. The chart was prepared from an initial series of ten, 10-minute counts using a U. S. Bureau of Standards Radium D + E standard source. This source was placed on the top shelf of the tube mount and covered with cellophane to shield the alpha and soft beta emissions. The average counting rate, less background, as well as the 95% and 99% limits of error were then calculated. These values were plotted on the Y-axis of the graph; values of time (usually days) were plotted on the X-axis. Parallel horizontal lines were drawn through the points showing the 95% limits of error.

Each day a 10-minute count, using the same standard source, was made and the average count, less background, was plotted on the control chart. If the value did not fall within the 95% limits two more counts were made. If only one of these two fell within the 95% limit the instrument was used but observed closely. If neither of these two values fell within the 95% limits the set was not used until it had been thoroughly serviced and a new control chart, with corresponding geometry, had been prepared.

The limit of error (L) was calculated from the equation (19).

$$L = \frac{K \sqrt{\dfrac{\sum_{i=1}^{N} X_i \; T}{N}}}{T}$$

$$= \frac{K \sqrt{\dfrac{\sum_{i=1}^{N} X_i}{NT}}}{}$$

Where K = 1.96 for 95% error

= 2.58 for 99% error

X = Net counting rate of one T-minute count

T = Time interval of counting, in minutes

N = Total number of "T"-minute counts and for the calibration

Due to the natural decay of the source, which had a half-life of 22 years, a new chart was prepared about once a month. If the indications were that the instrument was at fault, however, it was serviced before a new control chart was prepared.

The sample counting time, of course, will depend upon the activity present. Routine water samples and aquatic organisms were counted for not less than 5 minutes nor longer than 15 minutes. A total count of 1,280 was chosen as the minimum to be observed between these time limits. It can be shown (19) that samples reaching this count within 15 minutes result in a maximum statistical error of plus or minus 4.6% at the 90% confidence level, and plus or minus 5.4% at the 95% confidence level. The minimum reliable detectable activity with the G-M tube is 2 cpm or 0.6×10^{-8} μc/ml. for water samples and about 1×10^{-6} μc/gm. for biological samples.

CORRECTION FACTORS

To convert the relative value of counts to an absolute value of μc/ml. or μc/gm. it was necessary to apply various correction factors to the raw counts. Many of these factors had been determined by the Hanford Works Groups (20) (21) and were used initially by the Public Health Service group for routine work, while samples were being counted at the General Electric Company's counting facilities. These factors were:

Air and Mica-Window Absorption	: 1/0.97 or 1.03
Self-Absorption	: Variable with sample weight per unit area
Spread of Source	: 1/0.84 or 1.19
Backscatter (For Biological Samples)	: 1/1.38 or 0.72
Geometry	: 1/0.25 or 4.0
Decay Factor	: Variable with time between collection and counting, with type and location of of sample.
Background	: Variable from day to day. Generally 20 to 25, plus or minus 2 cpm.

However, due to differences in sampling locations of the two organizations, variations in G-M tubes, and the advisability of becoming acquainted with the aspects and techniques involved, the factors for air and mica-window absorption, self-absorption, spread of source, coincidence, geometry, decay, and background were measured separately by the Public Health Service group for the locations sampled.

Air and Mica-Window Absorption (AM-W)

A certain percent of the beta particles will not penetrate the air and mica-window due to their path length or energy. However, a reasonable correction can be made for this error by deriving an absorption curve for a particular kind of sample. Then, since the first portion of a beta particle absorption curve approximates an exponential relationship, a semi-logarithmic

plot of the counting rate versus absorber thickness gives a straight line. By extrapolating back to zero thickness through the point equivalent to the thickness of the window and air, a correction factor can be determined for any particular sample. Thin aluminum absorbers were used for deriving this factor.

Thus: $$f_{AM-W} = \frac{N_o}{N_x} = e^{mx} = 10^{\frac{mx}{2.3}}$$

Where: N_o = count rate without absorber

N_x = count rate with absorber "X" mg/cm^2 thick

m = absorption coefficient (Slope of the curve)

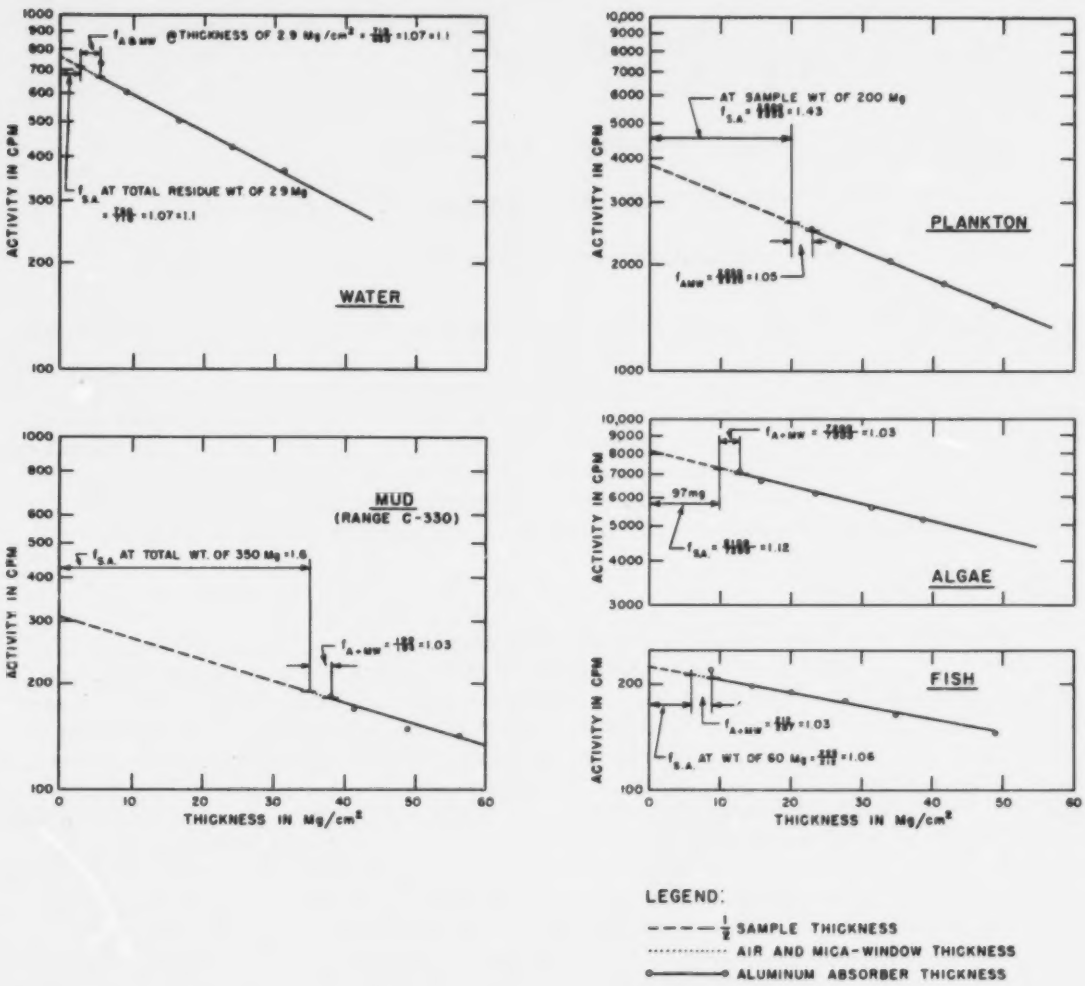
The thin aluminum absorbers used on this project varied in thickness as follows: 3.6, 7.1, 11.0, 14.9, 18.5, 21.8, 25.8, 28.6, 36.2, and 57.0 mg/cm^2. The air and mica-window were equivalent to 2.9 mg/cm^2. Figure A-2, page A-28, shows typical absorption curves. The factors given vary somewhat due to the difference in the isotopic content of the various types of samples. Water, for instance, has many low as well as high maximum energy beta emitters, while fish have predominantly the high energy P^{32} present, and thus only a minor correction is necessary for fish samples.

Self-Absorption (S-A)

For the low level work encountered in this study, the necessarily large samples created a significant amount of residue on the counting plate. This residue caused an absorption of some of the particles, especially those of low energy, and there was also some scattering. Since this mechanism is extremely complicated with a mixture of beta emitters, empirical determinations were necessary for all types of samples and for all expected residue weights. By using aluminum absorbers, as in the case above, and plotting the counting rate versus absorber thickness, an external absorption curve was obtained on semi-logarithmic paper which is very similar to a self-absorption curve. This curve was then extrapolated back the equivalent of the average or half the thickness of sample to find the true counting rate. Figure A-2, gives typical curves and values for all types of samples. The results varied greatly for various biological samples, values of from 1.00 to 2.50 being used, depending on the type and weight of sample. These values were repeatedly checked for all field and seasonal conditions, and the average values have been plotted in figure A-3, page A-29. A value of 1.1 was used consistently for water samples due to the uniformity of size (500 ml), and quality (50 to 70 ppm total solids).

Spread of Source (SS)

To determine the spread of source correction, a $Sr^{90} + Y^{90}$ "point" source was plated on a small, flat piece of stainless steel. The source was held at the first shelf level by means of a flat cardboard with offset edges. The displacement of the source from the axis of the tube was determined by graduations on the cardboard.



COLUMBIA RIVER STUDIES
1951 — 1953

TYPICAL ABSORPTION CURVES
(RANGE C-362)

Figure A-2

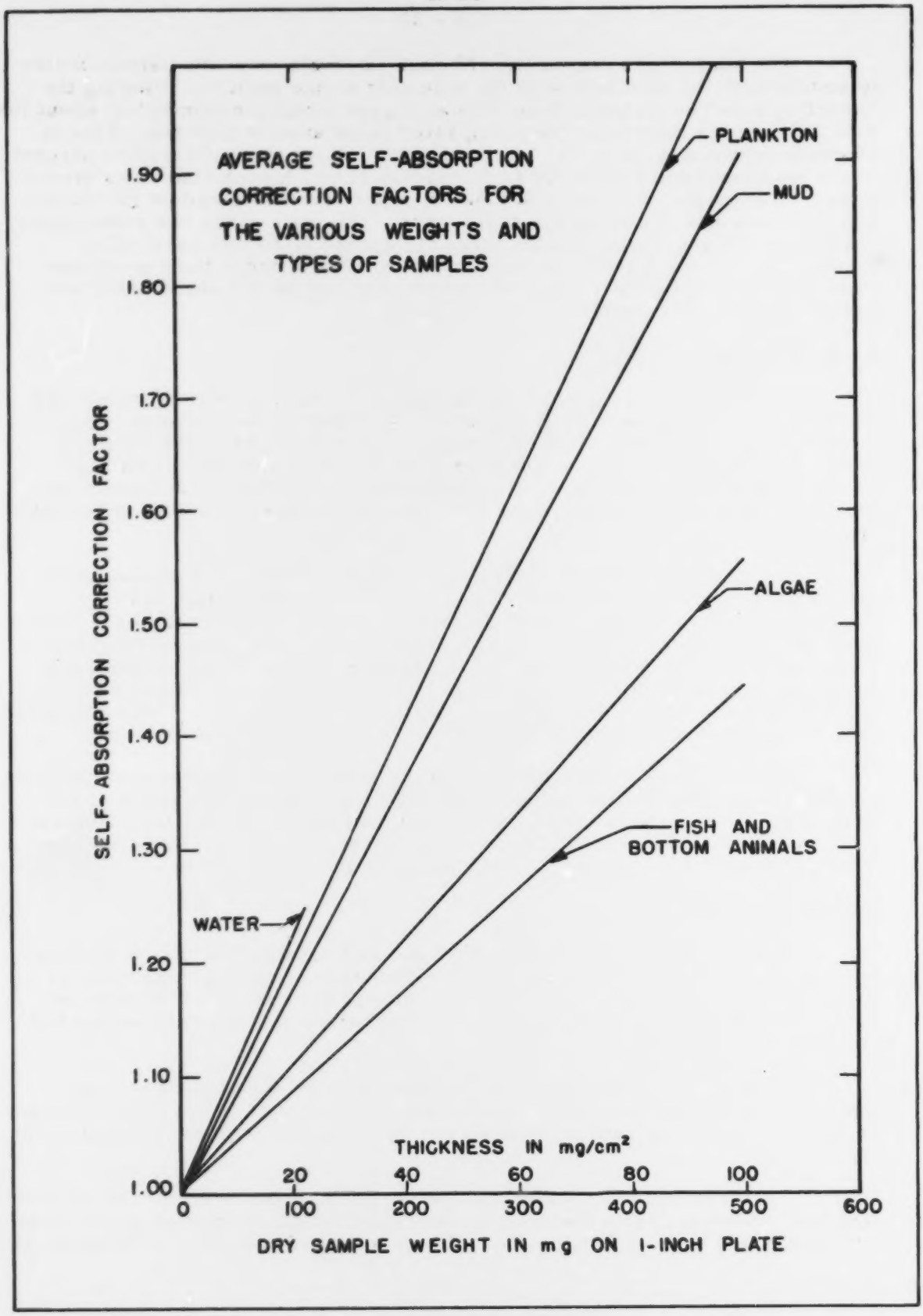

AVERAGE SELF-ABSORPTION CORRECTION FACTORS FOR THE VARIOUS WEIGHTS AND TYPES OF SAMPLES
PLANKTON
MUD
ALGAE
FISH AND BOTTOM ANIMALS
WATER
SELF-ABSORPTION CORRECTION FACTOR
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
THICKNESS IN mg/cm²
20
40
60
80
100
0
100
200
300
400
500
600
DRY SAMPLE WEIGHT IN mg ON 1-INCH PLATE

Figure A—3

The source was counted at 1/8-inch intervals on a line perpendicular to and through the tube axis with the tube axis at one position. Plotting the "counting rate" vs distance from tube axis gave a curve symmetrical about the tube axis, with a maximum "counting rate" value at zero distance. This is shown in figure A-4, page 31, "counting rate" values were changed to percent of the maximum and multiplied by the radius at which each count was determined. Then a plot was made of relative count rate times radius vs radius and a no loss line drawn on the same scale. The ratio of the two areas under the curves for any chosen radius gives the spread of source correction factor. For a 1-inch stainless steel plate on shelf 1 under the end-window G-M tube, the spread of source was found to be 1/0.84 for one counter and 1/0.81 for the other counter.

Coincidence Loss (CL)

Although a large part of the radiological counting on this project did not give results high enough to require a coincidence loss correction there were a few samples which did need such a correction. Also, the counting rate of the standard sources, used for geometry determination, was high enough (about 4,500 cpm) to make coincidence loss a significant factor. Only four runs were made to determine the coincidence loss on the two end-window G-M counters.

Eight pie-shaped pieces were cut from a flat disc of stainless steel. On each was plated a small spot of $Sr^{90} + Y^{90}$, counting about 400 cpm. Each source was assigned a position on a cardboard mount at the first shelf level and counted individually. It was assumed that there was no coincidence loss for these low counting rates. Then sources #1 and #2 were counted in their assigned positions and total count rates compared with the sum of the individual count rates. The total count rate from #1, #2, and #3 was compared with their sum and so on until all eight sources were counted together.

A plot of true count rate (total of the individuals) vs observed count rate was made and the coincidence loss read from the smooth curve shown in figure A-5, page A-32. For any one run the percent of loss per 1,000 cpm observed seemed to be about constant. However, the loss varied from about 1 to 2.5% per 1,000 cpm for various counters or various times.

Backscatter (BS)

Due to a lack of equipment and time, and because the values had been well-established by the General Electric Company no attempt was made to determine the backscatter factor. However, for the sake of reference and completeness of methods the general determination is given here as used at the Hanford Works (20).

Backscatter corrections for various isotopes mounted on several materials have been obtained by preparing point sources of the active isotopes on thin Formvar film, and measuring the counting rate with and without backing material.

The Formvar film, with a thickness of 0.3 to 0.5 mg/cm^2, is stretched taut and cemented over a flat aluminum ring. A small droplet of active isotope with negligible carrier is deposited at the center and carefully dried under an

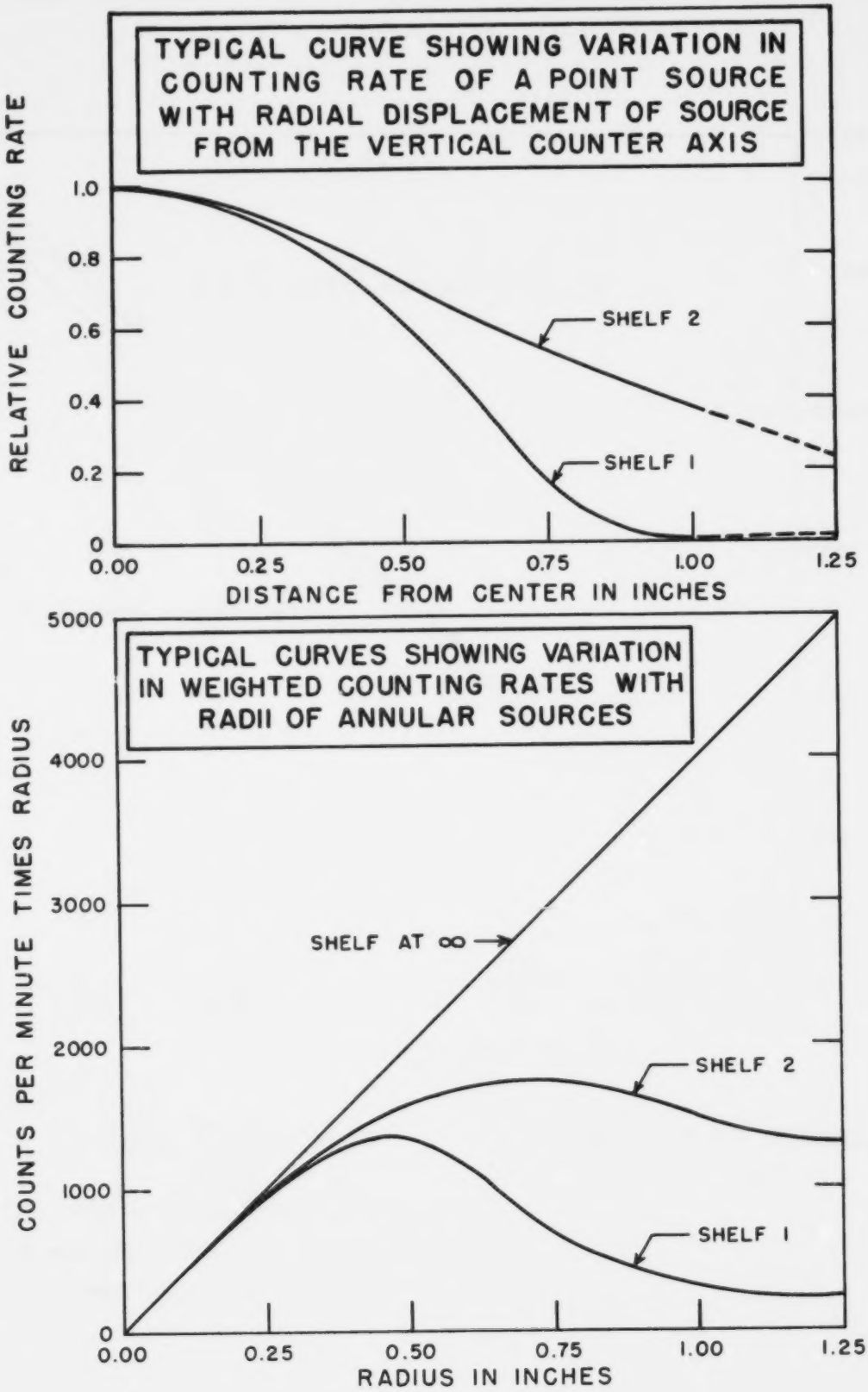
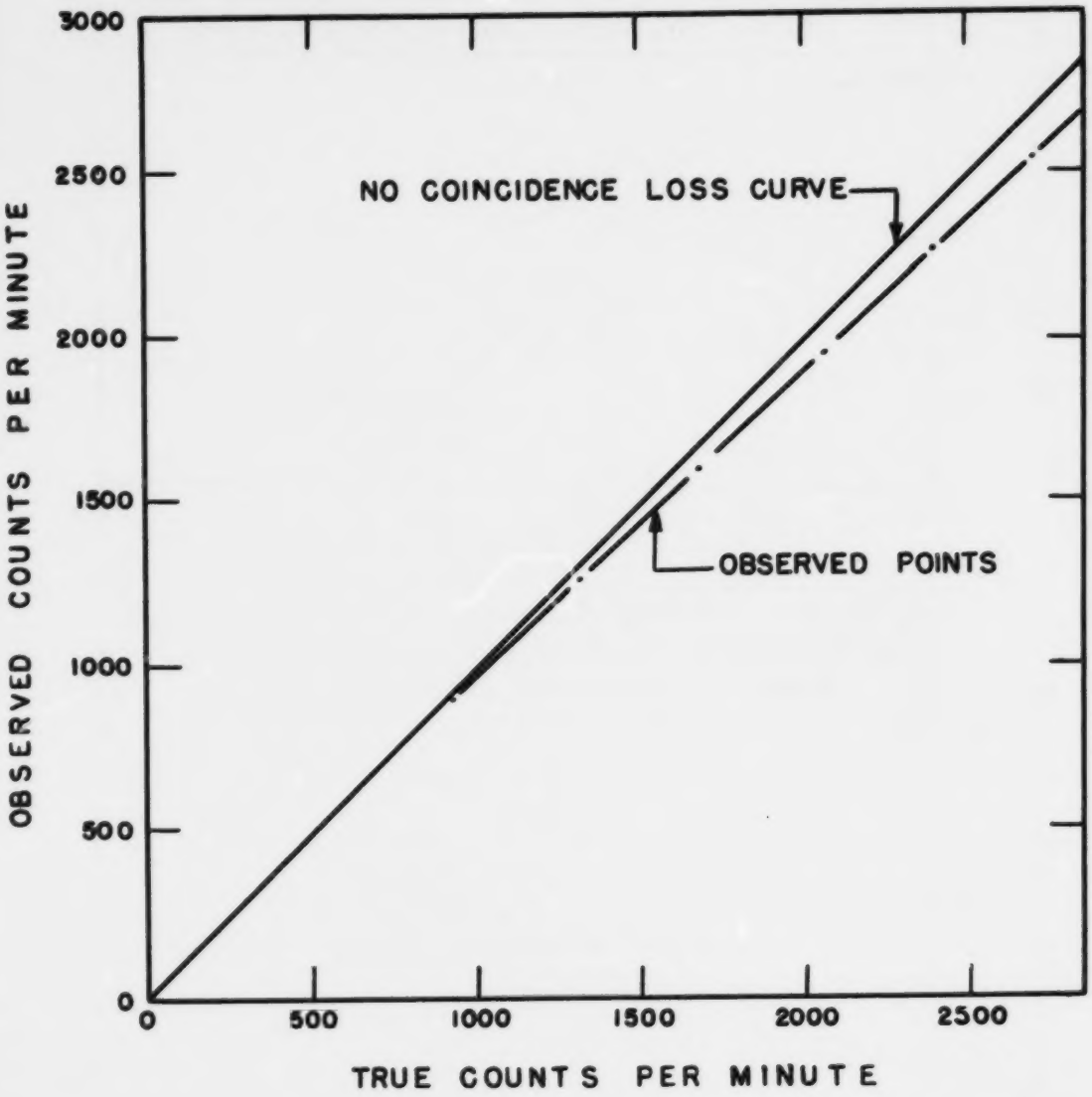

TYPICAL CURVE SHOWING VARIATION IN COUNTING RATE OF A POINT SOURCE WITH RADIAL DISPLACEMENT OF SOURCE FROM THE VERTICAL COUNTER AXIS
RELATIVE COUNTING RATE
1.0
0.8
0.6
0.4
0.2
0
SHELF 2
SHELF 1
0.00
0.25
0.50
0.75
1.00
1.25
DISTANCE FROM CENTER IN INCHES
TYPICAL CURVES SHOWING VARIATION IN WEIGHTED COUNTING RATES WITH RADII OF ANNULAR SOURCES
COUNTS PER MINUTE TIMES RADIUS
5000
4000
3000
2000
1000
0
SHELF AT ∞
SHELF 2
SHELF 1
0.00
0.25
0.50
0.75
1.00
1.25
RADIUS IN INCHES

Figure A-4



COLUMBIA RIVER STUDIES
1951—1953

COINCIDENCE LOSS
FOR
END WINDOW-GM TUBE COUNTER#3

CORRECTION: 2.2%/1000 cpm FOR
OVER 1000 cpm

Figure A-5

infra-red lamp. The film is mounted below the tube in such a manner that the distance to the tube face can be measured and that counts can be made with or without various kinds of backing material.

A measurement is made with no backing material, the backscatter disc (stainless steel in this case) is inserted just below the source film, and another count made. The ratio of the second count to the first is the backscatter factor, since the backscatter from the film is negligible. A factor of 1/1.38 was derived for P^{32} and was used for biological samples, while a factor of 1/1.35 was used for the mixture of radioisotopes in the river water (22).

Geometry (G)

Geometry can be defined as the fraction of the total solid angle about the source of radiation that is subtended by the face of the sensitive volume of a detector.

In the case of the G-M end-window counter, this has been obtained by correcting the counting rate of a source having a known disintegration rate for all known factors such as scatter, air and mica-window absorption, spread of source, and coincidence in the manner already given and recording the ratio of the corrected counting rate to the known disintegration rate of the source. This ratio is expressed by the following equation:

$$G = \frac{(cpm) \times (AM-W) \times (CL) \times (SS) \times (BS)}{dpm}$$

Where cpm = counts per minute

dpm = disintegrations per minute

Decay Factor (DF)

The radioactivity in the pile cooling water effluent is continually decreasing due to decay. The influence of this decay is very important when short half-lived isotopes are still present in the water and the sample transfer and preparation time is large. A theorectical consideration could have been given this factor, but due to the multiplicity of isotopes involved it appeared that an empirically derived decay curve would be necessary at each major sampling range and at each extreme in river stage. Such a curve permitted correction for the time interval between collection in the river and counting in the instruments.

The method for deriving these curves involved preparation of duplicate samples and counting the residue at frequent intervals. This preparation time was usually held to 1/2 to 1 hour for samples such as plankton or water which involved short half-lived isotopes. During the first 4 to 5 hours, counting at hourly intervals was found to be satisfactory for water and plankton samples. It was not necessary to count other samples, such as fish, as frequently.

Results were plotted on semi-logarithmic paper, with activity versus time. Then, with a fair knowledge of the characteristics of the isotopes

expected to be present, it was possible to extrapolate the curve back to zero or collection time. This was repeated many times over a period of months until it was apparent that a single curve was satisfactory for routine use. Changes in river stage did not alter the over-all flow time at C-362 and C-339 enough to significantly change the decay factor from one season to another.

Figure A-6, page A-35, shows a few typical decay curves as derived on this project. The values are plotted in terms of the percent activity remaining versus any particular time after collection in hours. Table A-1, page A-36, lists all the decay factors developed and used on this study. Figure A-6 also illustrates the average decay pattern for water, plankton, attached algae, bottom animals, and fish samples from all major cross sections of the study area. The curves are extended to cover a longer time interval than was normally necessary; that is, most water samples were counted before a lapse of 7 or 8 hours, and most biological samples were counted within 1 or 2 days. However, the nature of the isotopic content is revealed somewhat by extending these curves. In fact, the type of long half-life material is evident from the extended curves.

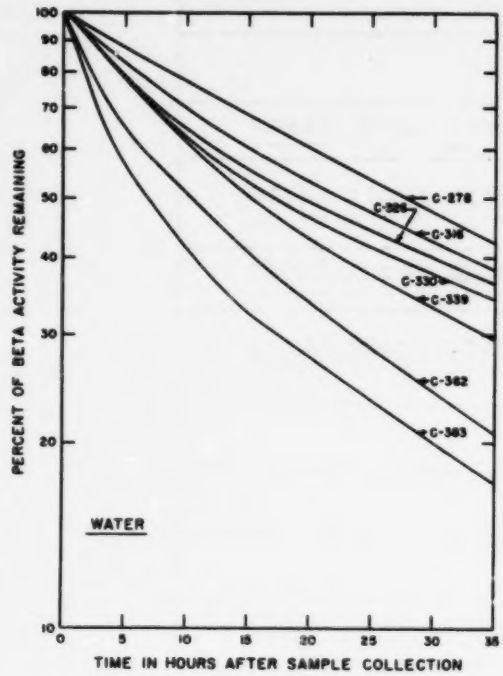
Background (B)

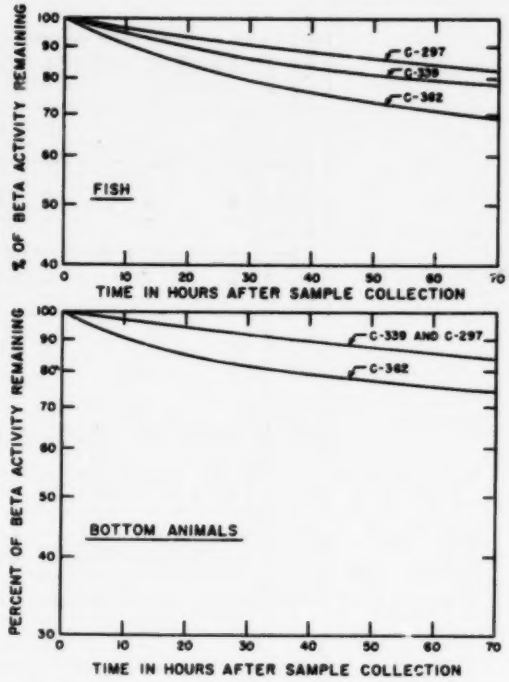
The natural or instrument background count is caused by cosmic radiation and radioactive substances in or near the counter. Since these may vary somewhat it is necessary to check the background daily or whenever there has been some suspected contamination of the counter.

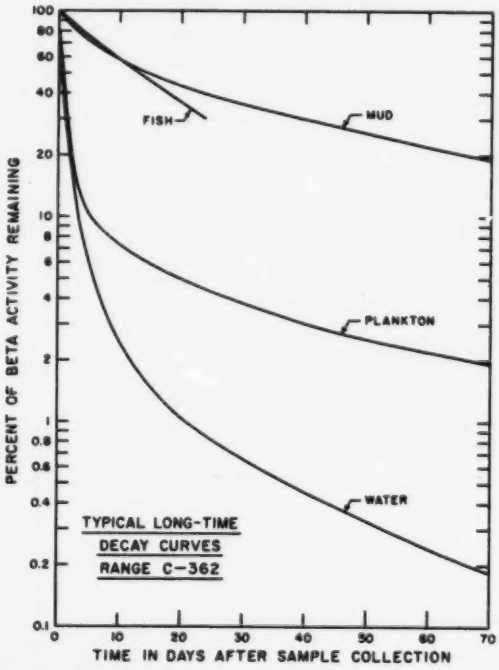
This is done by operating the counter without a sample below the end-window of the G-M tube. The reliability of this figure can be increased if it is determined from a long counting interval, such as a 16-hour over-night period. Under these circumstances the background value to be subtracted from all observed counts was about 22 cpm. It is understood, of course, that a close check is to be maintained on the consistency of overnight voltage, humidity and temperature conditions in the counting room, otherwise the overnight value may not be usable for daytime conditions. Generally, the background values varied only a few tenths of a count per minute from night to night. With a voltage regulator on the line to the counters and an air conditioner in the room it was possible to maintain reasonable control of the important variables.

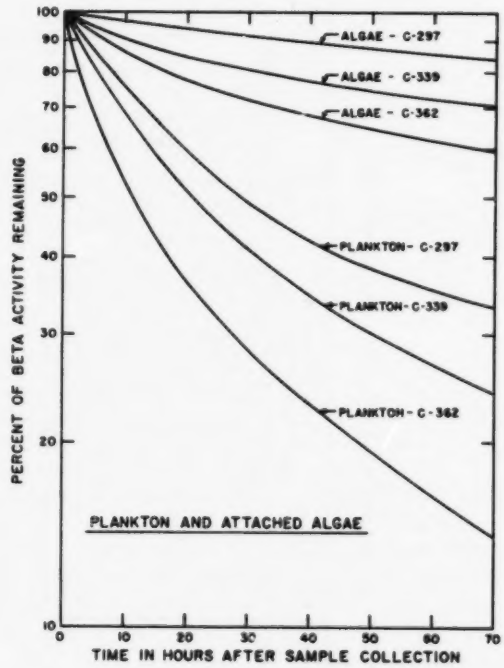
IDENTIFICATION OF BETA PARTICLE EMITTERS

The method for breaking down the beta particle emitters into chemical groups has been given previously. The principal objectives of this separation were to specifically identify the radioisotopes and to determine the amount of each present at the time the sample was collected. In order to do this, an initial count was necessary as soon as possible on the total sample, the insoluble portion, the soluble portion, and on the individual groups. The decay pattern was then determined by frequently recounting each sample. The results were plotted on semi-logarithmic paper, with the activity on the logarithmic scale. Decay of a single radioactive substance, being exponential, gives a straight line on such a plot; therefore, this method was helpful in illustrating the isotope or isotopes isolated by the chemical separation. Figure A-7, page A-37, shows the plot of a single radioisotope, the half-life of which is obtained by









COLUMBIA RIVER STUDIES
1951 — 1953

AVERAGE DECAY CURVES
(BY RANGES)

Figure A-6

Table A-1 - DECAY FACTORS FOR WATER AND BIOLOGICAL SAMPLES

Hours After Collection	Range:	C-383	C-362 (Hanford)					C-339 (Richland)					C-330	C-326	C-316	C-297 (McNary Dam Area)				C-278	Hours After Collection
	Sample:	Water	Water	Plankton	Algae	Bottom Animals	Fish	Water	Plankton	Algae	Bottom Animals	Fish	Water	Water	Water	Plankton	Algae	Bottom Animals	Fish	Water	
0		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0
1		1.12	1.11	1.10	1.02	1.01	1.01	1.05	1.04	1.01			1.05	1.05	1.04					1.03	1
2		1.30	1.22	1.19	1.03	1.02	1.02	1.09	1.09	1.02			1.09	1.09	1.09					1.05	2
3		1.47	1.34	1.29	1.05	1.03	1.03	1.14	1.13	1.04			1.14	1.14	1.12					1.08	3
4		1.60	1.44	1.39	1.07	1.04	1.04	1.20	1.19	1.05			1.20	1.19	1.17					1.11	4
5		1.75	1.52	1.47	1.09	1.05	1.05	1.27	1.22	1.06	1.02	1.03	1.27	1.25	1.21	1.15	1.02	1.02	1.02	1.14	5
6		1.89	1.61	1.54	1.10	1.06	1.06	1.35	1.27	1.07			1.35	1.32	1.25					1.17	6
7		2.04	1.70	1.61	1.12	1.07	1.07	1.43	1.31	1.08			1.43	1.40	1.30					1.20	7
8		2.15	1.79	1.69	1.14	1.08	1.08	1.50	1.35	1.09			1.48	1.45	1.34					1.23	8
9		2.30	1.86	1.78	1.16	1.10	1.09	1.58	1.40	1.10			1.54	1.50	1.39					1.26	9
10		2.46	1.94	1.87	1.18	1.11	1.10	1.65	1.45	1.11	1.03	1.06	1.60	1.55	1.43	1.32	1.03	1.03	1.04	1.29	10
15		3.08	2.40	2.32	1.23	1.14	1.14	2.00	1.72	1.15	1.04	1.09	1.89	-	1.67	1.49	1.05	1.04	1.06	1.45	15
20		3.63	2.98	2.85	1.29	1.17	1.18	2.36	1.97	1.18	1.06	1.12	2.08	-	1.93	1.68	1.06	1.06	1.07	1.67	20
25		4.27	3.53	3.22	1.34	1.19	1.22	2.61	2.18	1.21	1.07	1.14	2.44	2.26	2.22	1.87	1.08	1.07	1.09	1.89	25
30		5.00	4.17	3.50	1.38	1.21	1.26	3.00	2.40	1.24	1.09	1.16	2.62	-	-	2.04	1.09	1.09	1.10	2.10	30
35				3.92	1.43	1.23	1.30		2.65	1.27	1.10	1.18				2.20	1.11	1.10	1.11		35
40				4.33	1.47	1.25	1.33		2.98	1.30	1.11	1.20				2.38	1.12	1.11	1.13		40
45				4.75	1.51	1.26	1.35		3.18	1.32	1.13	1.21				2.49	1.13	1.13	1.14		45
50				5.26	1.55	1.28	1.37		3.38	1.34	1.14	1.23				2.60	1.15	1.14	1.15		50
55				5.89	1.59	1.30	1.39		3.51	1.36	1.16	1.24				2.70	1.16	1.16	1.17		55
60				6.06	1.62	1.31	1.41		3.71	1.38	1.17	1.26				2.80	1.17	1.17	1.18		60
65				6.67	1.65	1.33	1.43		3.94	1.40	1.19	1.27				2.90	1.18	1.19	1.19		65
70				7.15	1.67	1.35	1.45		4.20	1.42	1.20	1.29				3.02	1.20	1.20	1.21		70
75				7.70	1.70	1.36	1.47		4.39	1.44	1.21	1.30				3.12	1.21	1.21	1.22		75
80						1.38	1.49		4.58	1.46	1.23	1.31				3.16	1.23	1.23	1.24		80
85						1.40	1.50		4.77	1.48	1.24	1.32				3.20	1.24	1.24	1.25		85
90						1.42	1.51		4.95	1.50	1.25	1.34				3.25	1.25	1.25	1.27		90
95						1.44	1.52		5.13	1.52	1.26	1.36				3.30	1.26	1.26	1.28		95
100						1.46	1.53		5.31	1.53	1.28	1.37				3.34	1.28	1.28	1.30		100
105						1.48	1.54		5.49	1.55	1.29	1.38				3.40	1.29	1.29	1.31		105
110						1.50	1.55		5.67	1.57	1.30	1.39				3.45	1.30	1.30	1.32		110

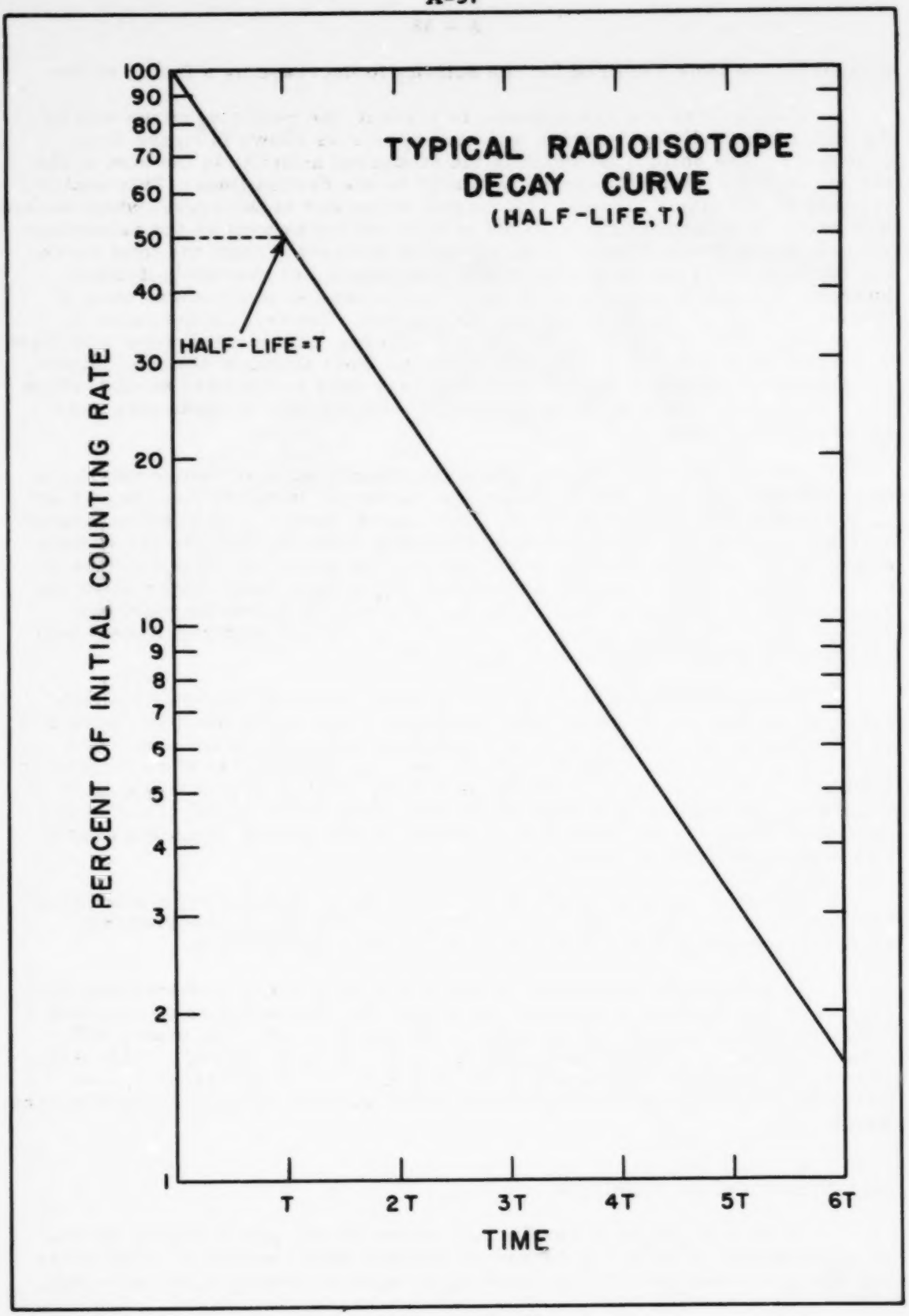

TYPICAL RADIOISOTOPE
DECAY CURVE
(HALF-LIFE, T)
HALF-LIFE = T
PERCENT OF INITIAL COUNTING RATE
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
T
2T
3T
4T
5T
6T
TIME

Figure A-7

measuring the time required for the activity to decrease by a factor of two.

If more than one radioisotope is present, the resulting curve will be the sum of the individual curves and may appear as shown in figure A-8, page A-39. The solid line, which is the measured activity, is the sum of the two exponential (straight) curves indicated by the dashed lines. This analysis is made by drawing a straight line tangent at the end of the curve, which makes it possible to determine the half-life of this isotope as well as the percentage present at any time. Then if this activity is subtracted from the total curve the residual will give the decay pattern and quantity of shorter half-lived isotope. It is possible to break a decay curve down in this manner even if there are three or more radioelements present. However, if the curve is more complex by virtue of many similar isotopes, this identification technique is not too satisfactory. During this study the most abundant short half-lived isotopes were readily detected, but for groups such as the rare earths, which had a constantly changing decay pattern, it was possible to make only generalized conclusions.

Still another technique to aid in the identification of radioelements is to extend the aluminum absorption curve, as shown in figure A-2, page A-28, up to between 400 and 600 mg/cm^2. This curve, being a plot of the measured activity as a function of thickness of absorbing material between the sample and detector, gives a measure of the penetrating power and thus an index of the radiation energy. The plot is made on semi-logarithmic paper since the absorption curve for any single beta ray spectrum will than be roughly a straight line. An ideal absorption curve for an isotope emitting 2 mev. beta particles is shown in figure A-9, page A-40.

The important characteristic of a beta absorption curve is the end-point, or the maximum range of the particles. This is the point on figure A-9 at which the curve appears to have completely bent over to the next more penetrating component. The exact location of an end-point is often difficult to determine. From a curve of the range-energy relationship (23), figure A-10, page A-41, the maximum energy of the beta particles is found. The flat end portion of the curve in figure A-9 is caused by any gamma radiation present which is not stopped by aluminum.

Figure A-11, page A-42, shows the absorption curve for a mixture of two activities of 1 mev. and 3 mev. energies, which can be resolved into their components and thus aid further in specific identification.

To adequately determine the percent of each major radioelement in a sample it was necessary to make corrections for the variables such as the differences in thickness and the time of the initial count. The means of obtaining these correction factors have already been discussed. Table A-2, page A-43, presents a summary of the raw data, correction factors, and percentage breakdown for a typical biological sample collected in the Columbia River.

CALCULATION OF RESULTS

In the calculation of results, to convert counts per minute to curies or microcuries, most of the correction factors were common for both water and biological samples, though differing in value according to the individual

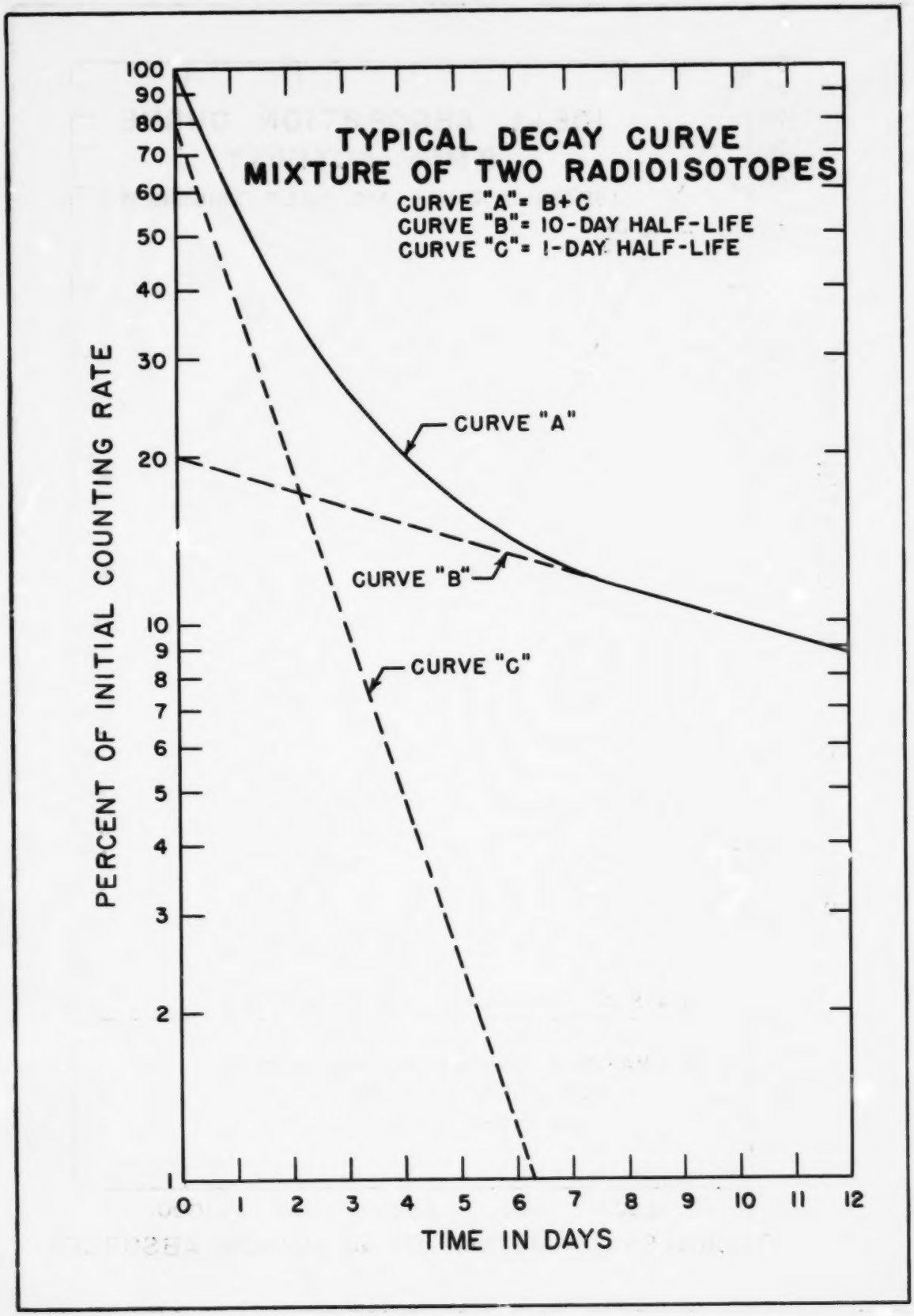

TYPICAL DECAY CURVE
MIXTURE OF TWO RADIOISOTOPES
CURVE "A"= B+C
CURVE "B"= 10-DAY HALF-LIFE
CURVE "C"= 1-DAY HALF-LIFE
CURVE "A"
CURVE "B"
CURVE "C"
PERCENT OF INITIAL COUNTING RATE
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME IN DAYS

Figure A-8

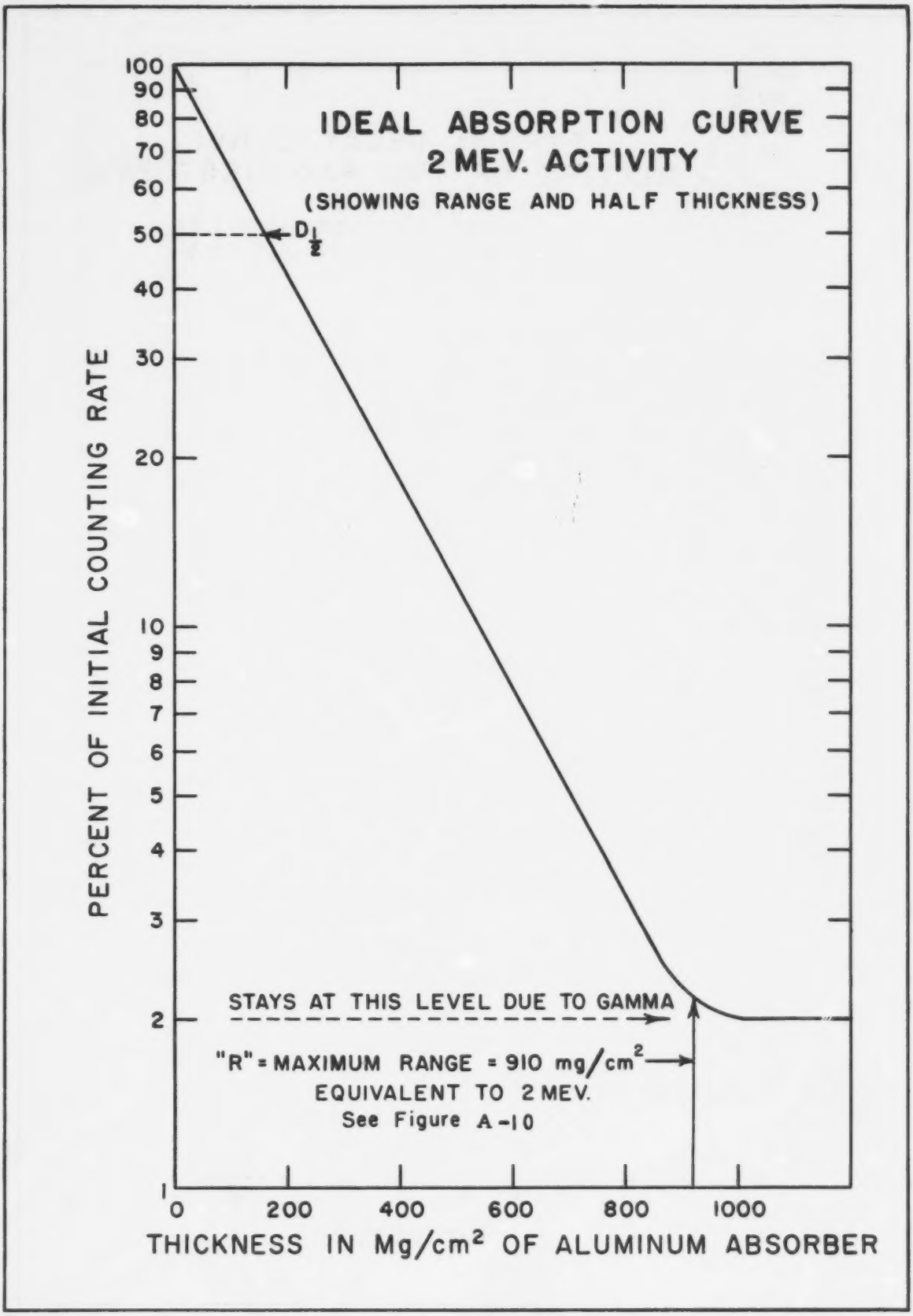

IDEAL ABSORPTION CURVE
2 MEV. ACTIVITY
(SHOWING RANGE AND HALF THICKNESS)
$D_{\frac{1}{2}}$
PERCENT OF INITIAL COUNTING RATE
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
STAYS AT THIS LEVEL DUE TO GAMMA
"R" = MAXIMUM RANGE = 910 mg/cm²
EQUIVALENT TO 2 MEV.
See Figure A-10
0
200
400
600
800
1000
THICKNESS IN Mg/cm² OF ALUMINUM ABSORBER

Figure A-9

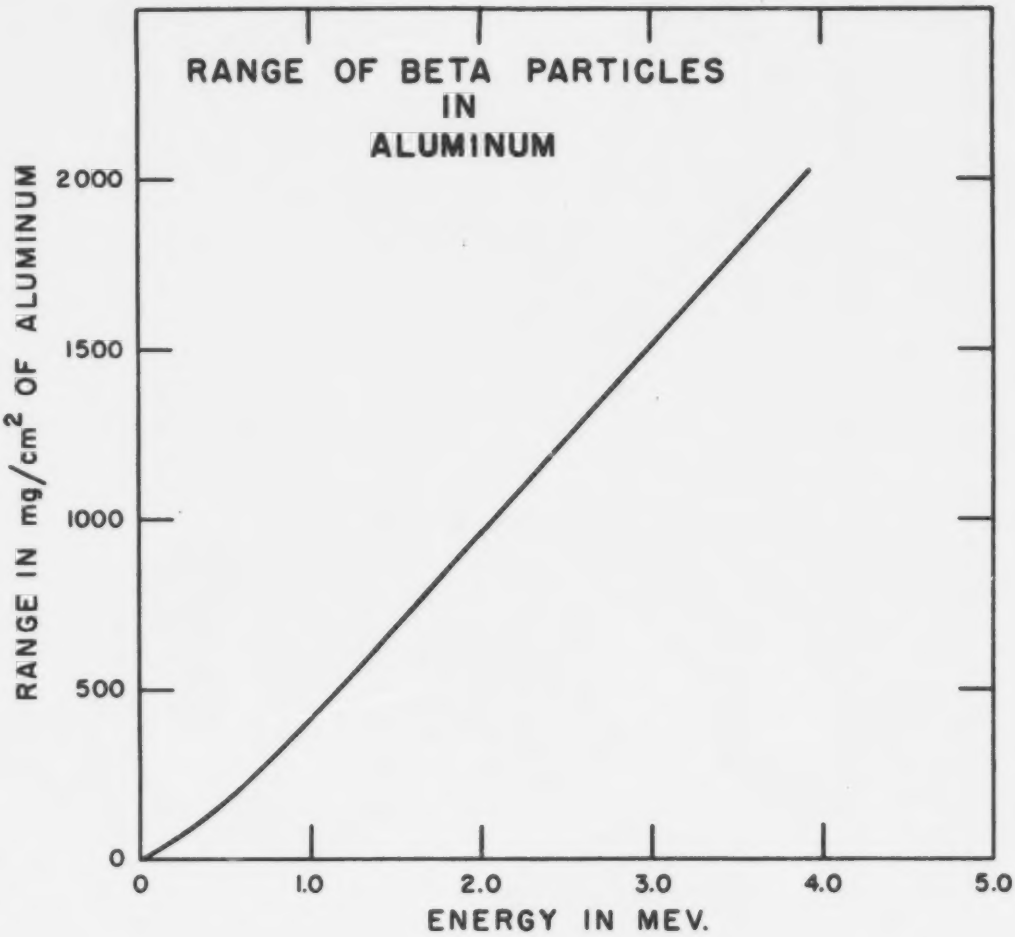

RANGE OF BETA PARTICLES
IN
ALUMINUM
RANGE IN mg/cm² OF ALUMINUM
2000
1500
1000
500
0
0
1.0
2.0
3.0
4.0
5.0
ENERGY IN MEV.

Figure A-10

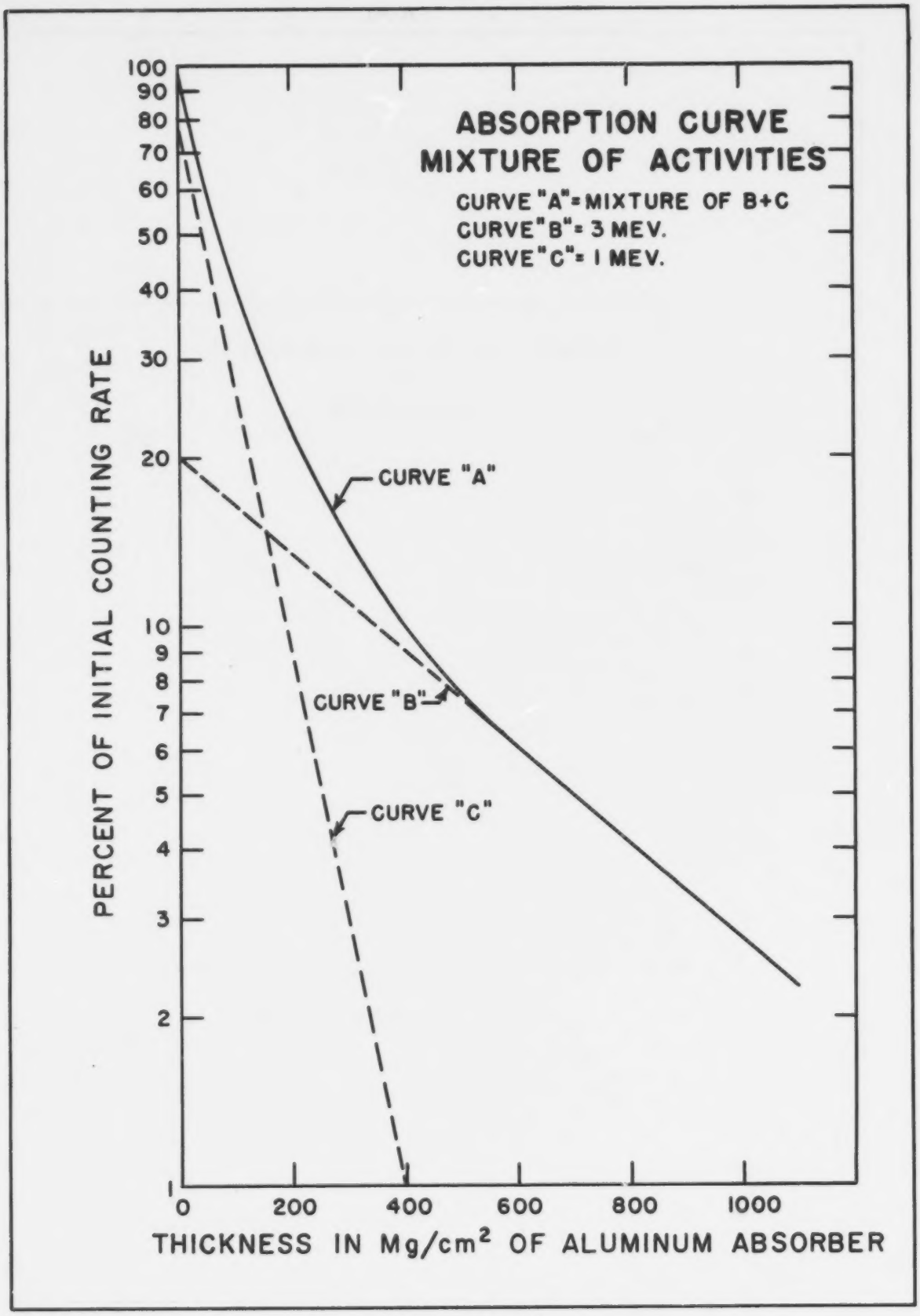

ABSORPTION CURVE
MIXTURE OF ACTIVITIES
CURVE "A" = MIXTURE OF B+C
CURVE "B" = 3 MEV.
CURVE "C" = 1 MEV.
CURVE "A"
CURVE "B"
CURVE "C"
PERCENT OF INITIAL COUNTING RATE
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0
200
400
600
800
1000
THICKNESS IN Mg/cm² OF ALUMINUM ABSORBER

Figure A-11

Table A-2 - TYPICAL SUMMARY SHEET FOR A RADIOCHEMICAL ANALYSIS

Sample No. R-34
Sample Description Algae (Ulothrix)

Date: Feb. 9, 1953
Location: C-362
Collection Time: 0830

Group	Estimated Half-Life	Duration of that Half-Life	Maximum Beta (Mev.)	Air & Mica-Window Correction	Weight of Samples (Grams)	Self-Absorption Correction Factor	Counts per Minute	Length of Time Counted (Minutes)	Time and Date of Count	Time Lapse Between Collection and Counting	Decay Correction Factor	Corrected Counts per Minute	Wet Weight of Sample (Grams)	Counts per Unit Weight (c/m/gm)	% of Total Soluble Portion
(O) Insoluble	11 days	15 days +	-	1.02 1.02 1.02	3 Portions 0.811 0.776 0.334	2.75 2.6 1.5	910 820 510	5 5 5	1535, 2-9 1541, 2-9 1547, 2-9	7 hrs. 7 hrs. 7 hrs.	1.02 1.02 1.02	2,600 2,200 800 5,600	18	310	-
(A) Total Soluble (in HNO_3)	3.5 days 10 days 21 days (Constantly	0-0.5 day 0.5 to 7 days 7 to 14 days changing)	-	1.04	0.025	1.04	2,620	5	1535, 2-9	7 hrs.	1.06	3,000	1	3,000	100
(B) Copper plus Some Long Half-Life	14 hrs. 34 hrs. 8 days	0-10 hrs. 24-50 hrs. 3 to 8 days	<1.3	1.08	0.027	1.07	420	5	1639, 2-9	8 hrs.	1.53	700	5	140	4.7
(C) Arsenic	26 hrs.	Only 1 half-life	>1.6	1.04	0.098	1.10	110	15	1710, 2-9	8.6 hrs.	1.25	160	5	32	1.1
(D) Phosphorus	14.5 days	0-15 days	1.4 +	1.03 1.03 1.03	3 Portions 1.396 1.217 0.488	3.2 2.8 1.5	1,850 1,930 480	5 5 5	1207, 2-10 1341, 2-10 1224, 2-10	27.5 hrs. 29 hrs. 28 hrs.	1.06 1.06 1.06	6,400 5,900 780 13,080	5	2,600	87
(E) Rare Earths	5 days 20 days	0 - 6 days 6 - 15 days	Some <1.0 Some 1.4	1.06	0.045	1.1	310	5	0849, 2-11	48 hrs.	1.3	480	5	95	3.2
(F) Iron and Chromium	7 days 16 days	0-4 days 7-15 days	not enough to work with	1.07	0.023	1.1	30	15	0904, 2-11	48.5 hrs.	1.2	41	5	8	0.3
(G & H) Zinc-Cobalt-Manganese	4 days Long Half-life	0-3 days over 3 days		1.1	0.084	1.3	90	10	1548, 2-10	31 hrs.	1.3	170	5	34	1.1
(I) Calcium							9	15	1026, 2-11	50 hrs.	(too little activity to work with effectively)				
(J) Sodium and Long Half-Life	3 days Long Half-life	0-2 days 2-4 days over 4 days		1.04	0.070	1.1	27	15	1023, 2-11	50 hrs.	Approx. 3.8	120	5	24	0.8

Total Activity as measured before separation = 3220 c/m/gm

Total Activity (Soluble + Insoluble) in c/m/gm -- 3310
Percent Insoluble -- 11%
Total Activity from Group Analysis of Soluble Portion-- 2933
Percent of Total Soluble Recovered -- 98%

sample. Some typical examples are given below.

It is known that

1 curie (c) = 3.7×10^{10} disintegrations per second (dps)

1 microcurie (μc) = 3.7×10^{4} dps

= 2.22×10^{6} dpm

1 dpm = $1/2.22 \times 10^{6} = 4.5 \times 10^{-7}$ μc

Therefore Conversion Factor (CF) = 4.5×10^{-7}

Water Samples

For purposes of illustration assume the following data on a particular end-window G-M counter and a specific water sample:

AM-W = 1/0.91 = 1.1 (for air and window thickness of 2.9 mg/cm^2)

SA = 1/0.91 = 1.1 (for 30 mg of sample on a 1-inch counting dish)

SS = 1/0.84 = 1.19 (for shelf at 0.191 inch from tube face)

BS = 1/1.35 = 0.74 (for stainless steel)

G = 1/0.30 = 3.3

Volume of Sample = 500 ml

Volume Factor (VF) = 1/500 = 0.002

Decay Factor (DF) = 1.4 (for a 4-hour delay, from table A-1)

Observed count = 5,100 counts in 5 minutes

= 1,020 cpm

Background (B) = 20 cpm

Corrected count = (Observed Count) - (Background Count)

= 1,020 - 20 = 1,000 cpm

Error (19) at 95%
Confidence Limit = ± 28 cpm (based on 1020 cpm @ 5 minutes)

Corrected count = 1000 ± 28 cpm

Then,

$$\text{Activity Density} = (\text{cpm}) \times (\text{AM-W}) \times (\text{SA}) \times (\text{SS}) \times (\text{BS}) \times (\text{G}) \times (\text{DF}) \times (\text{CF}) \times (\text{VF})$$

$$= (1000) \times (1.1) \times (1.1) \times (1.19) \times (0.74) \times (3.3) \times (1.4) \times (4.5 \times 10^{-7}) \times (0.002)$$

$$= 450 \times 10^{-8}\ \mu c/ml.$$

The 10^{-8} factor was used for presenting water results in tabular form since all results fell within the limits of 1 to 3000 x 10^{-8} μc/ml. This always gave an integer to the left of the decimal point. Due to the randomness of the disintegrations and the length of counting time, results were reported to only two significant figures. Corrected counts that were less than the statistical limits of the 95% confidence level were considered to be below the minimum detectable limit and were reported as "less than" values.

When using the internal flow counter for counting samples the same general calculations are necessary, though some of the correction factors are changed and others not necessary. The following data are assumed:

$$G = 1/0.50 = 2.0$$

Corrected Count = 2,150 cpm

All other factors remain the same, therefore

$$\text{Activity Density} = (\text{cpm}) \times (\text{SA}) \times (\text{BS}) \times (\text{G}) \times (\text{DF}) \times (\text{CF}) \times (\text{VF})$$

$$= (2150) \times (1.1) \times (0.74) \times (2.0) \times (1.4) \times (4.5 \times 10^{-7}) \times (0.002)$$

$$= 450 \times 10^{-8}\ \mu c/ml.$$

Biological Samples

For purposes of illustration assume the following data on a particular end-window G-M counter and, further, assume the sample to be fish in which P^{32} is the predominant radioisotope:

AM-W = 1/0.97 = 1.03

SA = 1/0.96 = 1.04

SS = 1/0.84 = 1.19

BS = 1/1.38 = 0.73

G = 1/0.30 = 3.3

Net weight of sample = 2.0 gms.

Weight Factor (WF) = 1/2 = 0.5

Decay Factor (DF) = 1.2 (for a 25-hour delay)

Corrected count = 200 cpm

Then,

Activity Density = (200) x (1.03) x (1.04) x (1.19) x (0.73) x (3.3) x (1.2) x (4.5×10^{-7}) x (0.5)

= $1{,}700 \times 10^{-7}$ μc/gm.

To facilitate handling of the results the 10^{-7} factor was used to present biological results in tabular form.

When using the internal flow counter the results were calculated in the same manner as shown above for water samples.

Mud Samples

The calculation of gross beta activity density for river muds is similar to that used for water and biological samples. Assume instrument and sample data as follows:

AM-W = 1/0.95 = 1.05

SA = 1/0.77 = 1.3

SS = 1/0.84 = 1.19

BS = = 1/1.35 = 0.74

G = 1/0.30 = 3.3

Weight of dry sample = 20 gms

Weight Factor (WF) = 1/20 = 0.05

Decay Factor (DF) = 1.2

Corrected Count = 50 cpm

Then,

Activity Density = (50) x (1.05) x (1.3) x (1.19) x (0.74) x (3.3) x (1.2) x (4.5×10^{-7}) x (0.05)

= 55×10^{-7} μc/gm.

As in the case of biological samples, the 10^{-7} factor was used in recording the results.

ALPHA RADIOACTIVITY COUNTING

Water and biological samples were not examined routinely for alpha (Pu + U) particle emitters, such determinations having been confined almost exclusively to a few mud samples. While the method of preparation given below is for muds the instrumentation and other matters discussed in this section are generally applicable for all types of samples.

PREPARATION OF MUD SAMPLES (24)

Reagents

1. Ethyl Ether
2. Conc. HNO_3
3. Distilled water
4. 2N HNO_3
5. Aluminum nitrate solution, prepared as follows:
   a. Place 5 pounds of $Al(NO_3)_3$ in a 2-liter Pyrex cylinder
   b. Add 1,500 ml distilled water
   c. Add 240 ml Conc. HNO_3
   d. Warm on hot plate until $Al(NO_3)_3$ is dissolved. Cool and use.
   e. Keep undissolved $Al(NO_3)_3$ in contact with solution at all times.

All mud samples were carefully prepared so that the residue on the counting plate was held to a minimum. The counting efficiency is impaired if the sample is much thicker than 0.1 mg/cm^2.

Procedure

1. Following the beta determination, bend the 1-inch planchet containing the sample and drop into a 250-ml glass-stoppered Erlenmeyer flask.
2. Add 20 ml aluminum nitrate solution.
3. Add 20 ml ether and shake for 15 minutes.
4. Separate ether from aqueous mixture in separatory funnel.
5. Put ether into 50-ml beaker and add 2 ml distilled water.
6. Evaporate under an infra-red lamp until ether is gone.

7. Transfer remaining solution to a flamed 1-1/2-inch stainless steel plate using 2N HNO_3 to complete the transfer.

8. Flame plate on a Bunsen burner.

9. Count for Alpha.

If a beta determination is not necessary, the method of preparation is somewhat modified as follows:

1. Dry all samples as for beta determinations.

2. Place 10 to 20 gram sample into 250-ml Erlenmeyer flask.

3. Add 50 ml Conc. nitric acid and slowly evaporate to dryness.

4. Add 10 ml 2N HNO_3 and heat to boiling. Swirl acid in flask. Cool.

5. Follow steps 2 to 9, as outlined above.

COUNTING EQUIPMENT

The internal flow or proportional counter was used for determination of alpha radioactivity.

An alpha particle is a doubly charged helium ion ejected from the nucleus with a velocity of about 2×10^{-9} cm/second. It produces a very high specific ionization of about 25,000 ion pairs per centimeter. So much of its energy is dissipated in this ionization that it has a very short range of from 1 to 11 cm in air and of only 0.001 inch in aluminum.

To measure the number of alpha particles emitted by a sample, it is necessary to introduce the sample directly into the chamber of the proportional counter.

The counter is referred to as an internal proportional counter, since the pulse height at any voltage is approximately proportional to the amount of ionization caused by the particle. A small but continuous flow of methane or methane-argon mixture through the chamber allows for an ionization which will not give rise to photoelectrons which, in turn, would interfere with the proportional response of the counter. With the aid of an amplifier, a discriminator, a fast scaling circuit, and a mechanical register, the number of pulses or counts are readily recorded.

The operating voltage must be determined before any routine counting is done. This is established by placing a sample with a high alpha count in the chamber and then measuring the counting rate at 50-volt intervals. A plateau in the count versus voltage curve occurs where a small change of voltage does not affect the counting rate. It was at this range, about 1,000 to 1,280 volts, that the alpha particles were discriminately counted.

The efficiency of this counter was about 50 percent, but it was most essential to avoid contamination of the instrument. This was particularly true

on this low level work where the subtracting of an incorrect background from each count could create a large percentage of error.

The counting unit is made up as follows:

1 Ea. Alpha Beta Gamma Proportional Flow Counter with Timer (Nuclear Measurements Corporation, Model PC-1 or equal)

1 Ea. Tank P-10, Gas (Argon-Methane Mixture)

1 Ea. Pressure Regulator

1 Ea. 30# Low Pressure Gauge

1 Ea. 300# High Pressure Gauge

Counting plates were similar to those used for beta work, except that the size was increased from 1 to 1-1/2 inches to permit a thinner sample.

CALCULATION OF RESULTS

Although water samples were not examined routinely for alpha activity the method of calculating the results is given below, along with a typical calculation for a mud sample.

As was stated in the section on beta radioactivity counting:

1 curie (c) $= 3.7 \times 10^{10}$ dps

1 microcurie (μc) $= 3.7 \times 10^{4}$ dps

$= 2.22 \times 10^{6}$ dpm

1 dpm $= 1/2.22 \times 10^{6} = 4.5 \times 10^{-7}$ μc

Therefore, Conversion Factor (CF) $= 4.5 \times 10^{-7}$

Water Samples

Assume the following data for a specific instrument and water sample:

SA = 1.0 (with sample thickness <0.1 mg/cm^2)

G = 1/0.50 = 2.0

Volume of sample = 500 ml.

Volume Factor (VF) = 1/500 = 0.002

Background count = 0.1 cpm

Observed count = 2.1 cpm

Corrected count = 2.1 - 0.1 = 2.0 cpm

Coincidence Loss = 0 (at low levels)

Chemical Yield (25) = 60%

Yield Factor (YF) = 1/0.60 = 1.67

Then,

Activity Density = (cpm) x (G) x (VF) x (YF) x (CF)

= (2.0) x (2.0) x (0.002) x (1.67) x (4.5×10^{-7})

= 0.6×10^{-8} μc/ml.

Mud Samples

Assumed data for the instrument and sample are:

SA = 1.0

G = 1/0.50 = 2.0

Weight of dry sample = 20 gms.

Weight Factor (WF) = 1/20 = 0.05

Background count = 0.1 cpm

Observed count = 10.1 cpm

Corrected count = 10.1 - 0.1 = 10.0 cpm

Chemical Yield = 60%

Yield Factor (YF) = 1/0.60 = 1.67

Then,

Activity Density = (cpm) x (G) x (WF) x (YF) x (CF)

= (10) x (2.0) x (0.05) x (1.67) x (4.5×10^{-7})

= 7.6×10^{-7} μc/gm.

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APPENDIX "B"

TABULATION OF INDIVIDUAL LABORATORY RESULTS

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Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River at	C-400	Surf.	2-25-52			2.0									8.2	68		
Priest Rapids		Comp.	3-10			4.5									8.2	65		
			4-16			7.0									8.1	68		
			4-28			9.0									8.0	62		
			5-12			10.0									8.0	58		
			6-2			12.0									7.9	55		
			7-28			17.0									8.0	57		
			8-11			19.0									8.0	58		
			9-15			17.0									8.0	57		
			10-13			17.5									8.0	59		
			11-10			13.0									8.0	61		
		10'-20'	1-28-52		<7	3.0	14.1								7.9	64		
			2-11		<7	4.0	13.5								7.9	66		
			3-24		<7	5.0	13.1								8.1	70		
			12-10		<7	10.0	9.7								8.0	65		
			1-19-53		<7	6.0	11.1								8.0	67		
			2-25		<7	6.0	11.4								8.0	68		
			3-17		<7	5.5	11.3								8.0	68		
		300'	8-13-51		4	18.0			0.02		0.05	0.03	8	0	8.0	73		
			9-4	460		18.0												
			9-11	110	6	17.5			0.01	0.00		0.04	12		8.0	86	0	<1
			9-24	930														
			10-15	930	4	15.0			0.02	0.00		0.05	10		8.2	65	0	<1
		700'	8-13-51		9	18.0	10.9		0.02		0.03	0.02	7	0	8.0	72		
			9-4	240	18	18.0	9.5	0.10	0.01	0.03	0.04	0.01	17		8.4	80	0	2
			9-11	430	11	17.5	9.5	0.03	0.02	0.02		0.00	22			74	0	<1
			9-24	2,400	8	17.5			0.01	0.00		0.04	9		8.0	80	0	2
			10-15	230	6	15.0			0.02	0.01		0.04	6		8.1	65	0	<1
			2-25-52		<7		13.8											
			3-10		<7		13.2											
			4-16		9		11.9											
			4-28		12		11.2											
			5-12		12		11.5											
			6-2		10		11.5											
			7-28		<7		11.3											
			8-11		<7		9.6											
			9-15		<7		8.9											
			10-13		<7		9.5											
			11-10		<7		9.1											
		1,200'	8-13-51		6	18.0			0.02		0.00	0.00	7	0	8.2	73		
			9-4	460		18.0												
			9-11	430		17.5												<1
			9-24	960	10	17.5			0.02	0.00		0.04	14		8.1	84	0	<1
			10-15	360	6	15.0			0.02	0.01		0.05	10		8.1	65	0	<1
Columbia River	C-390	Surf.	5-21-52										9					
below Priest		Comp.	7-30		2				0.02	0.01		0.02	10		8.1	58	0	
Rapids																		
		300'	11-8-51		5	12.5			0.02	0.04		0.00	13		8.2	62	0	<1
			11-19	930		10.0			0.04	0.02		0.04	11		7.8	69	0	<1
			12-13		5	7.0			0.00	0.00		0.02	12		7.8	67	0	<1
			2-11-52	91		2.0												<1
			2-18	36		2.0												<1
			5-21			10.0												<1
			7-30			16.0												<1
		600'	11-8-51		3	12.5			0.02	0.03		0.00	9		8.1	60	0	3
			11-19	430	5	10.0			0.04	0.02		0.01	9		7.8	69	0	<1
			12-13		5	7.0			0.00	0.00		0.03	10		7.5	65	0	2
			2-11-52	230		2.0												<1
			2-18	430		2.0												2
			5-21			10.0												<1
			7-30			16.0												<1

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River	C-390	900'	11-8-51		3	12.5			0.02	0.01		0.00	10		8.1	62	0	<1
below Priest			11-19	230	3	10.0			0.04	0.02		0.01	11		7.9	69	0	<1
Rapids (cont'd)			12-13		1	7.0			0.00	0.00		0.02	7		7.9	68	0	<1
			2-11-52	36		2.0												<1
			2-18	230		2.0												2
			5-21			10.0												<1
			7-30			16.0												<1
Columbia River	C-385	Surf.	4-28-52			9.0									8.1	62		
above Hanford		Comp.	5-8										14					
Works			5-12			10.0									8.0	58		
			9-23		4				0.02	0.00	0.10	0.04			8.1	57	0	
			12-1		3				0.18	0.00	0.06	0.00	13		7.9	62	0	
			1- 2-53		3	5.0			0.02	0.00	0.05	0.10	14		7.8	67	0	
			2-2		6				0.02	0.01	0.05	0.07	16		7.8	67	0	
			2-25			2.0									8.2	68		
			3-10			5.0									8.2	69		
			3-24			7.0									8.1	66		
			3-25		5				0.03	0.00	0.20	0.11	16		7.9	62	0	
			8-11			21.0									8.1	59		
			11-10			13.0									8.1	61		
			12-15			9.5									8.1	63		
		10'-20'	1-28-52		<7	4.0	14.2								8.1	64		
			2-11		<7	4.0	14.8								8.3	67		
		200'	8-24-51		6	17.5			0.02		0.04	0.12	10	0.6	8.0	61		
			9-13		18	17.5			0.01	0.02		0.00	22		8.1	77	0	<1
		500'	8-24-51		6	17.5	8.8	0.60	0.04		0.04	0.06	14	0	8.0	62		
			9-4		12	18.0	9.5	0.00	0.01	0.02	0.08	0.01	21		8.4	79	0	2
			9-13		11	17.5	8.8		0.02	0.02		0.02	27		8.0	77	0	1
			9-19		3	18.5			0.00	0.02		0.11	33		8.1	78	0	2
			9-26		6	16.0			0.00	0.00		0.05	15		8.2	76	0	<1
			10-4		6	16.5							15		7.9	72	0	
			10-18		4	15.0			0.02	0.00		0.06	11		8.1	64	0	1
			11-8		5	12.5			0.02	0.03		0.04	11		8.2	60	0	<1
			11-15		3	11.0			0.02	0.02		0.00	8		8.2	62	0	<1
			11-29		3	9.5			0.01	0.01		0.00	21			65	0	1
			12-6		5	8.0			0.02	0.01		0.05	14		7.8	70	0	<1
			1-10-52		7	3.0			0.03	0.03		0.07	5			64	0	
			1-16		3	3.0			0.00	0.00		0.10	3		7.8	67	0	
			1-24		7	2.0			0.02	0.02		0.08	12		7.9	73	0	<1
			1-31			2.0												<1
			2-7			2.0												<1
			2-18			2.0												<1
			2-25		<7		14.2											
			3-10		<7		13.2											
			3-24		<7		14.2											
			4-3			7.0												
			4-10			6.0												<1
			4-17			10.0												
			4-28		12		11.0											
			5-8			10.0												
			5-12		15		11.3											
			8-8			17.0												<1
			8-11		<7		9.6											
			8-19			16.0												1
			9-23			17.0												1
			11-10		<7		9.2											
			12-1			8.0												<1
			12-15		<7		10.2											
			1- 2-53			5.0												3
			2-2															12
			2-18															<1
			3-12			6.0												2.6
			3-18															<1
			3-25															1

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-9} µc/ml Gross Beta
Columbia River	C-385	800'	8-24-51		5	17.5			0.04		0.10	0.10	14	0	7.9	65		
above Hanford			9-13		13	17.5			0.02	0.02		0.01	30		8.0	77		1
Works (cont'd)																		
Columbia River	C-383	Surf.	9-19-51		8				0.00		0.02	0.05	32		8.1	77	0	
above Coyote		Comp.	2-25-52			2.0									8.2	69	0	
Rapids			3-10			5.0									8.2	67		
			3-24			7.0									8.1	68		
			4-16			7.0									8.1	69		
			4-28			9.0									8.0	62		
			5-12			10.0									7.9	58		
			6-2			12.5									8.0	53		
			6-2			12.5									8.0	53		
			7-28			17.0									8.0	56		
			8-11			20.0									8.1	57		
			9-15			17.0									8.0	58		
			10-13			17.5									8.1	59		
			11-10			13.0									8.1	60		
			12-15			9.5									8.1	63		
			3-17-53			5.5									7.9	67		
		10'-20'	1-28-52		<7	3.0	14.8								8.3	64	0	
			2-11		<7	3.5	14.2								7.9	65	0	
			1-19-53		<7	6.5	10.8								8.1	66		
			2-25		<7	6.0	11.9								8.2	68		
		200'	9-4-51	240		18.0				0.02	0.04				8.4	79	0	11
			9-13		12	17.5			0.01	0.02		0.03	22		8.0	79	0	59
			9-19	930														79
			9-26	930	11	16.0			0.01	0.00		0.06	15		8.2	76	0	140
			10-4		8	16.5							17		8.0	75	0	120
			10-18		14	15.0			0.02	0.00		0.04	8		8.1	69	0	330
			11-8		4	12.5			0.02	0.00		0.02	15		8.0	57	0	460
			11-15		10	11.0			0.01	0.03		0.00	13		8.1	64	0	520
			11-29		3	9.5			0.01	0.01		0.06	9			65	0	60
			12-6		7	8.0			0.03	0.01		0.05	14		8.0	64	0	460
			1-10-52		6	3.0			0.02	0.04		0.10	4		7.9	65	0	
			1-16		3	3.0			0.01	0.00		0.14	7		7.9	62	0	
			1-24		5	2.0			0.05	0.03		0.12	6		7.8	67	0	310
			1-31			2.0												260
			2-7			2.0												
			2-18			2.0												410
			4-3			7.0												150
			4-10			6.0												130
			4-17			10.0												61
			5-8			10.0												89
			5-15			10.0												1
			5-21			10.0												1
			5-28			11.0												<1
			6-24			12.0												<1
			7-3			13.0												1
			7-10			14.0												<1
			7-30			16.0												<1
			8-8			17.0												23
			8-19			16.0												190
			9-23			17.0												120
			12-1			5.0												600
			1-2-53			5.0												1,300
			2-2															32
			3-12			5.0												410
		300'	8-24-51		7	17.5			0.02		0.09	0.07	10	0	8.0	60		
			9-4			18.0			0.02			0.08						450
			9-13		18	17.5	9.1	0.10	0.01	0.02		0.02	24		8.0	79	0	140
			9-19															600
			9-26		6	16.0			0.00	0.00		0.04	11		8.1	75	0	290

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River above Coyote Rapids (cont'd)	C-383	300'	10-4-51		10	16.5							17		8.0	74	0	680
			10-18		8	15.0			0.02	0.00		0.04	4		8.0	66	0	450
			11-8		4	12.5			0.02	0.00		0.01	10		8.1	61	0	450
			11-15		11	11.0			0.01	0.02		0.00	15		8.1	64	0	760
			11-29		5	9.5			0.01	0.01		0.06	13			66	0	35
			12-6		5	8.0			0.03	0.01		0.04	14		8.0	69	0	480
			1-10-52		6	3.0			0.00	0.02		0.07	4		7.9	65	0	
			1-16		3	3.0			0.01	0.00		0.12	3		7.8	65	0	
			1-24		6	2.0			0.07	0.03		0.15	13		7.7	68	0	460
			1-31			2.0												530
			2-7			2.0												210
			2-18			2.0												710
			4-3			7.0												240
			4-10			6.0												920
			4-17			10.0												380
			5-8			10.0												37
			5-15			10.0												11
			5-21			10.0												18
			5-28			11.0												59
			6-24			12.0												<1
			7-3			13.0												530
			7-10			14.0												47
			7-30			16.0												100
			8-8			17.0												440
			8-19			16.0												470
			9-23			17.0												1,100
			12-1			8.0												1,200
			1-2-53			6.0												2,700
			2-2															1,900
			3-12			5.0												2,400
		400'	8-24-51		6	17.5	8.6	0.10	0.02		0.07	0.08	14	0.6	8.0	58		
			9-4	240		18.0				0.02	0.02				8.4	77	0	110
			9-13		17	17.5			0.01	0.01		0.02	19		8.0	79	0	120
			9-19	930														2
			9-26	73	7	16.0			0.01	0.00		0.06	13		8.2	75	0	<1
			10-4		10	16.5							15		8.0	73	0	31
			10-18		9	15.0			0.02	0.00		0.04	3		8.1	66	0	8
			11-8		3	12.5			0.02	0.02		0.00	10		8.1	61	0	92
			11-15		5	11.0			0.02	0.02		0.00	10		8.0	63	0	170
			11-29		3	9.5			0.01	0.01		0.07	11			71	0	<1
			12-6		5	8.0			0.03	0.01		0.04	14		7.9	75	0	7
			1-10-52		3	3.0			0.01	0.02		0.07	5		7.9	64	0	
			1-16		3	3.0			0.01	0.00		0.09	7		7.8	65	0	
			1-24		6	2.0			0.03	0.02		0.08	3		7.9	67	0	320
			1-31			2.0												240
			2-7			2.0												39
			2-18			2.0												190
			4-3			7.0												280
			4-10			6.0												180
			4-17			10.0												48
			5-8			10.0												210
			5-15			10.0												92
			5-21			10.0												250
			5-28			11.0												57
			6-24			12.0												<1
			7-3			13.0												<1
			7-10			14.0												190
			7-30			16.0												
			8-8			17.0												74
			8-19			16.0												36
			9-23			17.0												430
			12-1			8.0												700
			1-2-53			6.0												1,200
			2-2															180
			3-12			5.0												1,300

(1) Facing Upstream

Table B-I - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River	C-383	600'	8-24-51		5	17.5	8.3	0.30	0.05		0.09	0.04	11	0.3	8.0	60		
above Coyote			9-4		10	18.0	9.4	0.20	0.00	0.02	0.02	0.01	1[illegible]		8.4	78		2
Rapids (cont'd)			9-13		16	17.5			0.01	0.01		0.04	18		8.1	77	0	1
			9-26		7	16.0			0.01	0.00		0.04	14		8.2	74	0	<1
			10-4		10	16.5							20		8.0	74	0	2
			10-18		5	15.0			0.02	0.00		0.06	11		8.1	64	0	<1
			11-8		5	12.5			0.02	0.02		0.02	9		8.1	61	0	<1
			11-15		3	11.0			0.02	0.02		0.00	13		8.0	61	0	3
			11-29		2	9.5			0.01	0.01		0.07	12			68	0	<1
			12-6		13	8.0			0.03	0.02		0.04	13		7.9	70	0	1
			1-10-52		5	3.0			0.02	0.03		0.06	4		7.9	64	0	
			1-16		4	3.0			0.01	0.00		0.10	5		7.9	65	0	
			1-24		5	2.0			0.03	0.02		0.07	2		7.8	66	0	1
			1-31			2.0												<1
			2-7			2.0												<1
			2-18			2.0												<1
			2-25		<7		13.8											
			3-10		<7		13.2											
			3-24		<7		12.9											
			4-3			7.0												<1
			4-10			6.0												3
			4-16		7		11.8											
			4-17			10.0												2
			4-28		12		11.0											
			5-8			10.0												<1
			5-12		15		11.2											
			5-15			10.0												1
			5-21			10.0												<1
			5-28			11.0												<1
			6-2		10		11.3											
			6-24			12.0												2
			7-3			13.0												<1
			7-10			14.0												5
			7-28		<7		11.4											
			7-30			16.0												10
			8-8			17.0												<1
			8-11		<7		9.7											
			8-19			16.0												<1
			9-15		<7		9.0											
			9-23			17.0												2
			10-13		<7		9.4											
			11-10		<7		9.3											
			12-1			8.0												1
			12-15		<7		10.2											
			1-2-53			5.0												6
			2-2															<0.9
			3-12			5.0												9
			3-17		<7		11.4											
		800'	8-24-51		6	17.5			0.02		0.08	0.09	10	0.6	8.0	63		
			9-4	240		18.0				0.02	0.02				8.4	75	0	2
			9-13		11	17.5			0.01	0.01		0.04	22		8.1	77	0	1
			9-19	930														
			9-26	430	7	16.0			0.01	0.00		0.06	14		8.2	75	0	2
			10-4		10	16.5							12		8.0	76	0	<1
			10-18		9	15.0			0.02	0.00		0.02	10		8.1	61	0	<1
			11-8		5	12.5			0.04	0.03		0.00	11		8.2	61	0	<1
			11-15		3	11.0			0.02	0.03		0.00	13		8.1	62	0	2
			11-29		3	9.5			0.01	0.01		0.07	21			65	0	<1
			12-6		10	8.0			0.03	0.01		0.04	14		7.8	75	0	
			1-10-52		8	3.0			0.02	0.02		0.05	6		7.9	64	0	
			1-16		4	3.0			0.02	0.00		0.07	4		7.8	65	0	
			1-24		4	2.0			0.03	0.02		0.08	1		7.9	68	0	<1
			1-31			2.0												1
			2-7			2.0												1
			2-18			2.0												<1
			4-3			7.0												<1
			4-10			6.0												<1

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River	C-383	800'	4-17-52			10.0												2
above Coyote			5-8			10.0												<1
Rapids (cont'd)			5-15			10.0												3
			5-21			10.0												<1
			5-28			11.0												<1
			6-24			12.0												1
			7-3			13.0												<1
			7-10			14.0												<1
			7-30			16.0												<1
			8-8			17.0												2
			8-19			16.0												1
			9-23			17.0												<1
			12-1			8.0												2
			1-2-53			5.0												1
			2-2															<1
			3-12			5.0												1
Columbia River at	C-362	Surf.	1-28-52						0.01	0.01		0.08	[illegible]		7.9	63	0	
Hanford Ferry		Comp.	2-20									0.10	10					
Crossing			3-3												8.2	68		
			3-13									0.04	12					
			4-7			6.5									8.1	70		
			4-22			9.0									8.1	67		
			5-6			10.0									8.1	69		
			6-16			13.0									8.0	55		
			7-8			15.5									7.8	60		
			8-4			18.5									8.3	58		
			9-9			17.0									8.2	58		
			10-7			17.5									8.2	58		
			11-3			14.0									8.2	60		
			12-15			9.5									8.1	62		
		10'-20'	1-22-52		<7	4.0	12.9								7.8	65		
			2-5		<7	4.0	13.4								7.9	65		
			2-18		<7	3.5	13.5								8.0	66		
			3-17		<7	4.0	13.3								8.0	69		
			2-10-53		<7	6.0	11.0								8.0	64		
			3-25		<7	8.0	11.4								8.0	66		
		100'	8-24-51		7	18.0			0.05		0.10	0.10	10		8.2	64		
			9-11	230	9	18.0	9.6	0.10	0.02	0.03		0.02	22		8.1	75	0	1,200
			9-17	210	15	18.5			0.05	0.01		0.00	10		8.1	80	0	890
			9-24	430	3	17.5			0.02	0.00		0.04						600
			10-4		5	17.0							15		7.9	74	0	850
			10-11		3	17.0			0.01	0.00		0.02	13		8.2	76	0	680
			10-17	230	7	15.0			0.03	0.00		0.08	8		8.1	63	0	480
			10-24	150	6	14.0			0.04	0.00		0.05	14		8.1	63	0	990
			11-1		2	11.0			0.01	0.01		0.04	10		8.1	66	0	550
			11-15		5	11.0			0.01	0.02		0.00	13		8.0	69	0	1,200
			11-19	230	3	10.5			0.03	0.01		0.00	10		7.9	70	0	1,300
			11-29		3	9.5			0.01	0.01		0.06	10			68	0	1,500
			12-5															420
			12-6		12	8.0			0.03	0.02		0.03	16		7.9	67	0	580
			12-13		5	7.0			0.00	0.00		0.03	10		8.0	68	0	1,000
			1-7-52		3	4.0			0.05	0.01		0.00	6		7.6	68	0	
			1-17		5	3.0			0.03	0.01		0.07	1		8.1	63	0	
			1-23		4	2.0			0.07	0.02		0.09	11		8.1	67	0	1,200
			1-28			1.0												540
			1-31			2.0												620
			2-7			2.0												1,300
			2-11			2.0												1,100
			2-21			2.0												1,200
			2-27			2.0												1,200
			3-13			3.0												610
			4-1			7.0												1,200
			4-10			6.0												630
			4-17			10.0												920
			5-8			10.0												590

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River at	C-362	100'	5-15-52			10.0												390
Hanford Ferry			5-22			10.0												290
Crossing (cont'd)			5-28			11.0												290
			6-9			12.0												360
			6-17			13.0												340
			6-24			12.0												210
			7-1			12.0												420
			7-9			14.0												200
			7-17			16.0												450
			7-28			17.0												780
			8-4			17.0												780
			8-13			18.0												770
			8-19			16.0												290
			9-15			16.0												720
			9-23			18.0												1,100
			11-17			11.0												500
			12-16															940
			1-9-53			7.0												1,600
			1-13			7.0												920
			2-9			5.0												1,100
			2-20			4.0												710
			3-12			6.0												1,300
		800'	8-24-51		6	18.0			0.02		0.05	0.01	11	0.6	7.8	64		
			9-11		11	18.0	9.4	0.30	0.04	0.03		0.00	20		8.1	75	0	770
			9-17		28	18.5			0.05	0.00		0.00	13		8.1	81	0	700
			9-24		3	17.5			0.02	0.00		0.02						630
			10-4		8	17.0							13		8.1	74	0	810
			10-11		3	17.0			0.01	0.00		0.02	11		8.2	76	0	330
			10-17		13	15.0			0.03	0.00		0.02	9		8.1	64	0	540
			10-24		5	14.0			0.04	0.00		0.05	12		8.2	65	0	640
			11-1		2	11.0			0.02	0.01		0.00	12		8.1	64	0	660
			11-15		6	11.0			0.02	0.02		0.00	9		8.1	68	0	1,100
			11-19		3	10.5			0.03	0.01		0.01	9		7.9	69	0	1,300
			11-29		6	9.5			0.01	0.01		0.08	8			67	0	840
			12-6		9	8.0			0.03	0.01		0.02	15		7.8	71	0	510
			12-13		6	7.0			0.00	0.00		0.01	7		7.9	68	0	1,100
			1-7-52		4	4.0			0.05	0.02		0.02	5		7.7	68	0	
			1-17		2	3.0			0.02	0.01		0.08	3		8.1	61	0	
			1-23		5	2.0			0.06	0.02		0.12	10		8.0	56	0	710
			1-28			1.0												520
			1-31			2.0												750
			2-7			2.0												1,200
			2-11			2.0												1,300
			2-21			2.0												1,100
			2-27			2.0												1,100
			3-3		<7		13.8											
			3-13			3.0												630
			4-1			7.0												
			4-7		8		12.1											
			4-10			6.0												640
			4-17			10.0												1,000
			4-22		10		11.1											
			5-6		20		11.5											
			5-8			10.0												430
			5-15			10.0												110
			5-22			10.0												230
			5-28			11.0												160
			6-9			12.0												240
			6-16		7		11.3											
			6-17			13.0												330
			6-24			12.0												220
			7-1			12.0												410
			7-8		<7		11.3											
			7-9			14.0												150
			7-17			16.0												320
			7-28			17.0												620
			8-4		<7		9.8											570

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River at	C-362	800'	8-13-52			18.0												730
Hanford Ferry			8-19			16.0												300
Crossing (cont'd)			9-9		<7		9.4											
			9-15			16.0												910
			9-23			18.0												1,300
			10-7		<7		8.5											
			11-3		<7		9.2											
			11-17			11.0												610
			12-13		<7		10.3											
			12-16															1,100
			1- 9-53			7.0												1,900
			1-13			7.0												1,300
			2-9			5.0												940
			2-20			4.0												660
			3-12			6.0												1,200
		1,000'	8-24-51		7	18.0	8.9	0.30	0.05		0.10	0.07	16		7.8	62		
			9-11	73	12	18.0	9.4	0.30	0.04	0.03		0.02	26		8.1	74	0	500
			9-17	460	17	18.5			0.05	0.00		0.05	14		8.1	78	0	290
			9-24	230	3	17.5			0.01	0.00		0.02						650
			10-4		11	17.0							16		8.1	75	0	
			10-11		1	17.0			0.01	0.00		0.03	6		8.2	77	0	540
			10-17	2,400	12	15.0			0.02	0.01		0.02	8		8.0	63	0	630
			10-24	430	3	14.0			0.03	0.00		0.05	14		8.1	64	0	680
			11-1		2	11.0			0.04	0.01		0.02	11		7.9	74	0	740
			11-15		5	11.0			0.01	0.02		0.00	15		8.1	68	0	1,100
			11-19	230	3	10.5			0.03	0.02		0.01	14		7.9	69	0	920
			11-29		6	9.5			0.01	0.01		0.06	12			66	0	700
			12-6		6	8.0			0.04	0.01		0.02	15		8.0	68	0	570
			12-13		5	7.0			0.00	0.00		0.03	15		8.1	70	0	890
			1- 7-52		9	4.0			0.08	0.02		0.05	10		7.8	69	0	
			1-17		3	3.0			0.03	0.02		0.07	1		8.1	62	0	
			1-23		5	2.0			0.05	0.02		0.11	10		8.0	66	0	490
			1-31			2.0												730
			2-7			2.0												860
			2-11			2.0												1,100
			2-21			2.0												690
			2-27			2.0												980
			3-13			3.0												610
			4-1			7.0												890
			4-10			6.0												440
			4-17			10.0												710
			5-8			10.0												310
			5-15			10.0												85
			5-22			10.0												130
			5-28			11.0												110
			6-9			12.0												91
			6-17			13.0												240
			6-24			12.0												210
			7-1			12.0												220
			7-9			14.0												150
			7-17			16.0												170
			7-28			17.0												310
			8-4			17.0												280
			8-13			18.0												450
			8-19			16.0												350
			9-15			16.0												590
			9-23			17.0												1,100
			11-17			11.0												650
			1- 9-53			6.0												920
			1-13			7.0												1,200
			2-9			5.0												940
			2-20			4.0												650
			3-12			6.0												940
		1,300'	8-24-51		5	18.0			0.02		0.06	0.01	10	0.6	8.0	60		
			9-11	230	12	18.0	9.4	0.30	0.03	0.03		0.00	30		8.1	76	0	980
			9-17		19	18.5			0.05	0.00		0.00	20		8.1	79	0	360

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River at	C-362	1,300'	9-24-51		3	17.5			0.02	0.00		0.02						600
Hanford Ferry			10-4		7	17.0							15		8.1	73	0	560
Crossing (cont'd)			10-11		3	17.0			0.01	0.00		0.02	7		8.1	78	0	400
			10-17		8	15.0			0.02	0.00		0.02	6		8.1	62	0	520
			10-24		7	14.0			0.04	0.00		0.05	12		8.1	65	0	600
			11-1		2	11.0			0.04	0.01		0.02	11		8.0	65		490
			11-15		7	11.0			0.02	0.03		0.00	15		8.1	65		590
			11-19		3	10.5			0.04	0.02		0.01	13		7.9	66		610
			11-29		7	9.5			0.01	0.01		0.06	13			64		520
			12-6		7	8.0			0.03	0.01		0.04	14		8.0	70	0	550
			12-13		5	7.0			0.00	0.00		0.04	14		8.1	70	0	470
			1-7-52		4	4.0			0.05	0.01		0.03	6		7.8	67	0	
			1-17		2	3.0			0.02	0.01		0.09	3		8.1	61	0	
			1-23		6	2.0			0.05	0.02		0.06	13		8.0	67	0	330
			1-28			1.0												330
			1-31			2.0												530
			2-7			2.0												450
			2-11			2.0												510
			2-21			2.0												400
			2-27			2.0												310
			3-13			3.0												530
			4-1			7.0												570
			4-10			6.0												350
			4-17			10.0												470
			5-8			10.0												190
			5-15			10.0												160
			5-22			10.0												120
			5-28			11.0												79
			6-9			12.0												80
			6-17			13.0												120
			6-24			12.0												180
			7-1			12.0												78
			7-9			14.0												180
			7-17			16.0												160
			7-28			17.0												270
			8-4			17.0												250
			8-13			18.0												310
			8-19			16.0												240
			9-15			16.0												440
			9-23			17.0												450
			11-17			11.0												590
			12-16															960
			1-9-53			6.0												650
			1-13			7.0												1,100
			2-9			5.0												620
			2-20			4.0												450
			3-12			5.0												320
		1,600'	8-24-51		6	18.0			0.04		0.06	0.06	10	0	8.0	63		
			9-11	230	12	18.0	9.4	0.30	0.03	0.03		0.00	20		8.1	75	0	260
			9-17	43	13	18.5			0.08	0.02		0.06	16		8.1	78	0	210
			9-24	91	4	17.5			0.02	0.00		0.02						460
			10-4		7	17.0							17		8.1	74	0	390
			10-11		4	17.0			0.04	0.00		0.02	10		8.2	79	0	210
			10-17	430	13	15.0			0.03	0.00		0.02	6		8.2	63	0	320
			10-24	430	11	14.0			0.04	0.00		0.06	15		8.1	66	0	210
			11-1		3	11.0			0.02	0.01		0.04	10		8.0	51	0	320
			11-15		8	11.0			0.01	0.02		0.00	11		8.2	66	0	420
			11-19	430	3	10.5			0.04	0.02		0.00	11		7.9	69	0	360
			11-29		14	9.5			0.03	0.02		0.07	10			66	0	240
			12-6		8	8.0			0.04	0.02		0.04	14		7.9	71	0	300
			12-13		5	7.0			0.00	0.00		0.02	10		8.0	68	0	410
			1-7-52		2	4.0			0.04	0.02		0.01	11		7.6	69	0	
			1-17		3	3.0			0.04	0.01		0.10	7		8.1	62	0	
			1-23		4	2.0			0.03	0.02		0.06	10		8.0	67	0	1,000
			1-28			1.0												190
			1-31			2.0												
			2-7			2.0												280

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River at Hanford Ferry Crossing (cont'd)	C-362	1,600'	2-11-52			2.0												360
			2-21			2.0												340
			2-27			2.0												330
			3-13			3.0												340
			4-1			7.0												370
			4-10			6.0												180
			4-17			10.0												280
			5-8			10.0												110
			5-15			10.0												410
			5-22			10.0												94
			5-28			11.0												88
			6-9			12.0												100
			6-17			13.0												74
			6-24			12.0												110
			7-1			12.0												150
			7-8			14.0												220
			7-17			16.0												100
			7-28			17.0												190
			8-4			17.0												140
			8-13			18.0												180
			8-19			16.0												150
			9-15			16.0												240
			9-23			17.0												400
			11-17			11.0												380
			12-16															770
			1-8-53			6.0												500
			1-13			7.0												770
			2-9			5.0												370
			2-20			4.0												180
			3-12			5.0												490
Columbia River at Richland, Wash.	C-339	Surf. Comp.	1-25-52		4	2.0			0.07	0.00		0.07	4		8.0	62	0	
			2-21									0.10	12					
			3-3			3.0									8.2	68		
			3-18			4.0									8.1	72		
			4-7			6.5									8.1	70	0	
			4-22			9.0									8.0	66	0	
			5-5			10.0									8.1	68	0	
			5-7										19					
			5-22										9					
			6-17			13.0									8.0	55	0	
			6-19		2				0.01	0.00		0.10	10		8.0	56	0	
			7-8			16.0									8.0	55		
			8-4			19.0									8.2	57		
			9-9			17.0									8.1	57		
			10-6			17.5									8.1	57		
			11-19		3				0.07	0.01	0.03	0.04	13		7.9	61	0	
			12-19			8.5									8.0	68		
			1-8-53		4	6.0			0.03	0.00	0.00	0.05	18		8.0	51	0	
		10'-20'	1-22-52		<7	4.0	13.0								7.7	67		
			2-5		<7	4.0	13.1								8.0	68		
			2-18		<7	3.0	16.1								8.5	69		
			2-10-53		<7	6.0	11.0								8.0	65		
			3-27		<7	[illegible]	11.1								8.0	67		
		100'	8-14-51		6	19.0	10.7	0.60	0.02		0.00	0.02	7	0	8.3	76		
			8-23		6	18.0	8.4		0.01	0.01		0.00	8	0	8.1	67		
			8-30		2	17.0	9.3	1.0	0.03	0.04	0.07	0.02	11	0	8.4	76	0	
			9-6		7	18.5				0.04		0.00						170
			9-17	430	17	18.5			0.04	0.02		0.08	17		8.2	79	0	290
			10-1	750	3	17.0			0.01	0.01			12		8.0	75	0	240
			10-10	230	6	17.5			0.02	0.00		0.05	14		8.1	80	0	190
			10-18		6	14.5			0.02	0.00		0.04	10		8.0	70	0	270
			10-22		8	13.0			0.03	0.00		0.03	11		8.0	67	0	380
			10-24	430	4	13.0			0.00	0.00		0.03	11		8.0	67	0	330
			10-29	150	3	13.5			0.00	0.02		0.00	5		7.9	85	0	220
			11-6		3	11.5			0.02	0.00		0.01	12		8.1	70	0	220

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River at	C-339	100'	11-21-51		7	10.0			0.02	0.01		0.05	10		8.0	65	0	330
Richland, Wash.			11-27	110	3	9.0			0.03	0.01		0.08	14		8.0	69	0	380
(cont'd)			12-12	150	5	6.5			0.02	0.02		0.02	3		7.9	67	0	400
			1-7-52		3	4.0			0.05	0.02		0.07	6		7.9	68	0	
			1-16		4	3.0			0.00	0.00		0.08	5		7.9	65	0	
			1-17			3.0			0.03	0.02			3		7.9	51	?	
			1-24		4	2.0			0.03	0.02		0.10	9		7.8	68	0	330
			1-30			2.0												290
			2-6			2.0												
			2-21			2.0												320
			3-27			8.0												360
			3-31			8.0												300
			4-2			7.5												330
			4-14			7.0												250
			4-18			10.0												290
			4-29			10.0												290
			5-7			10.0												140
			5-13			11.0												150
			5-22			10.0												100
			5-27			11.0												100
			6-5			12.0												97
			6-19			12.0												150
			6-26			14.0												63
			7-1			13.0												120
			7-9			14.0												85
			7-16			16.0												110
			7-28															180
			7-29			17.0												
			8-6			18.0												72
			8-13			18.0												190
			8-19			16.0												120
			9-3			17.0												220
			9-8			16.0												260
			9-29			17.0												370
			11-19			10.0												370
			12-24			6.0												210
			1-8-53			6.0												600
			1-13			7.0												400
			2-9			5.0												350
			2-26			5.0												350
			3-11															430
		500'	8-14-51		7	19.0	10.4	0.60	0.01		0.03	0.05	9	0.4	8.3	75		
			8-23		6	18.0	8.4	0.10	0.01	0.02		0.00	10	0.0	8.0	65		
			8-30		2	17.0	9.3	0.70	0.05	0.06	0.05	0.02	12	0.0	8.4	79	0	
			9-6		7	18.5				0.03		0.12						180
			9-17		11	18.5			0.02	0.02		0.00	21		8.1	82	0	320
			10-1		3	17.0			0.01	0.01			11		8.0	75	0	250
			10-10		7	17.5			0.00	0.01		0.06	15		8.2	78	0	210
			10-18		7	14.5			0.01	0.00		0.04	12		8.1	70	0	300
			10-22		8	13.0			0.02			0.07	9		8.1	66	0	380
			10-24		4	13.0			0.00	0.00		0.07	9		8.1	66	0	300
			10-29		3	13.5				0.01		0.00	4		8.0	80	0	300
			11-6		3	11.5			0.02	0.00		0.00	12		8.2	65	0	130
			11-21		5	10.0			0.02	0.01		0.05	12		7.9	67	0	350
			11-27		2	9.0			0.03	0.01		0.04	15		8.0	65	0	500
			12-12		3	6.5			0.02	0.02		0.02	9		7.9	66	0	450
			1-7-52		5	4.0			0.05	0.02		0.12	5		7.7	66	0	
			1-16		3	3.0			0.01	0.00		0.10	3		7.7	65	0	
			1-17		3	3.0			0.03	0.02		0.08	4		8.1	62	0	
			1-24		6	2.0			0.03	0.02		0.07	6		7.9	69	0	260
			1-30			2.0												280
			2-6			2.0												
			2-21			2.0												340
			3-27			8.0												340
			3-31			8.0												330
			4-2			7.5												360
			4-14			7.0												280

(1) Facing Upstream

Table B-I - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River at Richland, Wash. (cont'd)	C-339	500'	4-18-52			10.0												400
			4-29			10.0												330
			5-7			10.0												130
			5-13			11.0												130
			5-22			10.0												86
			5-27			11.0												55
			6-5			12.0												100
			6-19			12.0												120
			6-26			14.0												83
			7-1			13.0												120
			7-9			14.0												110
			7-16			16.0												120
			7-29			17.0												180
			8-6			18.0												140
			8-13			18.0												190
			8-19			16.0												150
			9-3			17.0												370
			9-8			16.0												310
			9-29			17.0												370
			11-19			10.0												490
			12-24			6.0												290
			1-8-53			6.0												630
			1-13			7.0												520
			2-26			5.0												480
			3-11															440
		1,000'	8-14-51		7	19.0	10.1	1.0	0.01		0.05	0.09	6	0	8.3	73		
			8-23		8	18.0	8.5	0.10	0.01	0.03	0.07	0.00	8	0	8.0	62		
			8-30		1	17.0	9.3	0.40	0.01	0.03	0.04	0.03	12	0	8.4	75	0	
			9-6		9	18.5				0.03		0.00						160
			9-17	230	16	18.5			0.02	0.02		0.00	16		8.1	82	0	360
			10-1	430	4	17.0			0.01	0.01			11		8.0	73	0	270
			10-10	230	7	17.5			0.00	0.01		0.05	14		8.2	80	0	230
			10-18		7	14.5			0.02	0.00		0.02	12		8.1	70	0	340
			10-22	930	8	13.0			0.02	0.00		0.04	11		8.1	65	0	270
			10-24	210	4	13.0			0.00	0.00		0.06	11		8.1	65	0	260
			10-29	930	3	13.5				0.01		0.02	7		8.1	80	0	300
			11-6		4	11.5			0.02	0.00		0.00	13		8.1	65	0	230
			11-21		6	10.0			0.02	0.01		0.05	12		8.0	70	0	330
			11-27	2,400	3	9.0			0.04	0.01		0.04	15		8.0	70	0	460
			12-12	230	5	6.5			0.01	0.02		0.03	11		7.9	67	0	370
			1-7-52		5	4.0			0.04	0.01		0.01	6		7.5	67	0	
			1-16		5	3.0			0.03	0.00		0.12	4		7.7	66	0	
			1-17		4	3.0			0.03	0.01		0.07	2		8.1	62	0	
			1-24		5	2.0			0.04	0.02		0.05	13		7.9	67	0	320
			1-30			2.0												390
			2-6			2.0												
			2-21			2.0												350
			3-3		<7		13.5											
			3-18		8		12.9											
			3-27			8.0												370
			3-31			8.0												330
			4-2			7.5												340
			4-7		8		12.1											
			4-14			7.0												280
			4-18			10.0												340
			4-22		10		11.2											
			4-29			10.0												320
			5-5		19		11.1											
			5-7			10.0												120
			5-13			11.0												120
			5-22			10.0												72
			5-27			11.0												120
			6-5			12.0												89
			6-17		<7		11.1											
			6-19			12.0												120
			6-26			14.0												74
			7-1			13.0												100

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River at	C-339	1,000'	7- 8-52		<7		11.2											
Richland, Wash.			7-9			14.0												110
(cont'd)			7-16			16.0												120
			7-29			17.0												160
			8-4		<7		9.7											
			8-6			18.0												120
			8-13			18.0												160
			8-19			16.0												150
			9-3			17.0												380
			9-8			16.0												210
			9-9		<7		9.2											
			9-29			17.0												440
			10-6		<7		8.7											
			11-4		<7		9.5											
			11-19			10.0												450
			12-19		<7		10.2											
			12-24			6.0												270
			1- 8-53			6.0												680
			1-13			7.0												580
			2-20			5.0												440
			3-11															430
		1,500'	8-14-51		6	19.0	10.3	0.60	0.06		0.05		7		8.2	73		
			8-23		9	18.0	8.4	0.30	0.01	0.03		0.00	11	0	8.0	62		
			8-30		1	17.0	9.2	0.40	0.04	0.06	0.06	0.07	11	0	8.4	74	0	
			9-6		9	18.5				0.03		0.00	0					180
			9-17		12	18.5			0.03	0.02		0.01	18		8.2	80	0	350
			10-1		3	17.0			0.01	0.01			15		8.0	76	0	260
			10-10		13	17.5			0.00	0.02		0.05	17		8.2	80	0	220
			10-18		8	14.5			0.02	0.00		0.02	8		8.1	70	0	290
			10-22		5	13.0			0.02	0.00		0.04	10		8.1	65	0	270
			10-24		3	13.0			0.00	0.00		0.05	10		8.1	65	0	290
			10-29		3	13.5				0.02		0.00	9		8.1	80	0	300
			11-6		4	11.5			0.03	0.00		0.00	11		8.2	65	0	220
			11-21		5	10.0			0.02	0.02		0.05	14		8.0	66	0	340
			11-27		3	9.0			0.02	0.01		0.05	14		8.0	70	0	420
			12-12		3	6.5			0.02	0.02		0.02	11		7.9	62	0	290
			1- 7-52		3	4.0			0.05	0.02		0.00	6		7.7	66	0	
			1-16		3	3.0			0.00	0.00		0.10	4		7.8	66	0	
			1-17		3	3.0			0.02	0.01		0.06	4		8.1	61	0	
			1-24		7	2.0			0.04	0.02		0.05	4		7.9	66	0	310
			1-30			2.0												350
			2-6			2.0												
			2-21			2.0												320
			3-27			8.0												240
			3-31			8.0												290
			4-2			7.5												340
			4-14			7.0												280
			4-18			10.0												310
			4-29			10.0												90
			5-7			10.0												[illegible]
			5-13			11.0												[illegible]
			5-22			10.0												[illegible]
			5-27			11.0												[illegible]
			6-5			12.0												[illegible]
			6-19			12.0												[illegible]
			6-26			14.0												69
			7-1			13.0												74
			7-9			14.0												96
			7-16			16.0												100
			7-29			17.0												160
			8-6			18.0												96
			8-13			18.0												110
			8-19			16.0												130
			9-3			17.0												320
			9-8			16.0												270
			9-29			17.0												400
			11-19			10.0												470

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River at	C-339	1,500'	12-24-52			6.0												300
Richland, Wash.			1-8-53			6.0												630
(cont'd)			1-13			7.0												550
			2-26			5.0												430
			3-11															390
		1,900'	8-14-51		7	19.0	10.4	1.0	0.05		0.00	0.02	7		8.3	73		
			8-23		12	18.0	8.9		0.02	0.04		0.00	8	0.6	8.0	65		
			8-30		2	17.0	9.6	1.3	0.03	0.06	0.04	0.02	18	0	8.4	75	0	
			9-6		11	18.5				0.04		0.00	19		8.1	81	0	120
			9-17	73	11	18.5			0.03	0.01		0.00						250
			10-1	930	4	17.0			0.01	0.01			9		8.0	72		140
			10-10	150	5	17.5			0.00	0.02		0.03	16		8.2	80		220
			10-18		11	14.5			0.02	0.00		0.02	11		8.0	70	0	250
			10-22	430	9	13.0			0.03	0.00		0.04	10		8.1	65	0	260
			10-24	930	4	13.0			0.00	0.00		0.06	10		8.0	65	0	250
			10-29	230	3	13.5				0.00		0.00	9		8.1	80	0	220
			11-6		3	11.5			0.03	0.04		0.00	11		8.2	65	0	150
			11-21		5	10.0			0.02	0.02		0.04	10		7.9	66	0	280
			11-27	230	6	9.0			0.04	0.02		0.06	16		8.0	72	0	350
			12-12	91	7	6.5			0.02	0.03		0.02	11		7.9	67	0	350
			1-7-52		4	4.0			0.03	0.01		0.00	7		7.8	66	0	
			1-16		3	3.0			0.01	0.00		0.09	4		7.9	65	0	
			1-18		2	3.0			0.03	0.01		0.07	2		8.1	61	0	
			1-24		6	2.0			0.04	0.02		0.05	6		7.8	71	0	220
			1-30			2.0												280
			2-6			2.0												
			2-21			2.0												260
			3-27			8.0												250
			3-31			8.0												240
			4-2			7.5												280
			4-14			7.0												180
			4-18			10.0												260
			4-19			10.0												250
			5-7			10.0												38
			5-13			11.0												66
			5-22			10.0												53
			5-27			11.0												27
			6-5			12.0												68
			6-19			12.0												69
			6-26			14.0												38
			7-1			13.0												73
			7-9			14.0												79
			7-16			16.0												96
			7-29			17.0												140
			8-6			18.0												230
			8-13			18.0												110
			8-19			16.0												120
			9-3			17.0												320
			9-8			16.0												210
			9-29			17.0												380
			11-19			10.0												420
			12-24			6.0												300
			1-8-53			6.0												590
			1-13			7.0												520
			2-26			5.0												330
			3-11															340
Columbia River	C-330	Surf.	2-19-52									0.05						
above Kennewick,		Comp.	3-3			3.0									8.2	69		
Wash.			3-17			4.0									8.0	68		
			4-8			7.0									8.1	70		
			5-5			10.0									8.0	75		
			5-7										12					
			5-19										10					
			6-9			13.0									8.1	55		
			6-19		3				0.02	0.00		0.14	8		8.1	59	0	
			7-8		3				0.02	0.01		0.04	5		7.9	58	0	

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River	C-330	Surf.	7-29-52		8				0.00	0.00		0.00	12		8.3	58	0	
above Kennewick		Comp.	8-5			19.0									8.2	60		
Wash. (cont'd)			9-8			18.0									8.2	61		
			9-17		5				0.05	0.00	0.12	0.04			8.2	65	0	
			11-26		3				0.00	0.00	0.07	0.01	13		7.9	78	0	
		10'-20'	1-21-52		<7	3.0	13.0								8.0	71		
			2-4		10	4.0	12.4								7.9	70		
			2-18		<7	3.5	13.0								8.0	120		
			4-21		12	10.0	11.1								8.0	85		
			3-24-53															95
		200'	8-21-51		5	19.0	8.3	0.10	0.01		0.06	0.01	9	0.2	8.0	84		
			8-30		4	17.5	10.9	2.9	0.06		0.18	0.06	25	5.0	8.5	140	6	
			9-6		8	19.0			0.04	0.05	0.04	0.00	8		8.1	86	0	130
			9-12	230	15	17.5			0.02	0.04		0.04	31		8.3	100	3	150
			9-19	91														190
			9-26	200	8	16.5			0.02	0.00		0.05	14		8.2	87	0	220
			10-2	430	6	17.0							14		7.9	85	0	160
			10-11		8	17.0			0.03	0.00		0.04	9		7.9	87	0	160
			10-17	430	4	14.0			0.02	0.02		0.02	9		8.0	76	0	190
			10-22	930	11	13.5			0.03	0.00		0.08	18		8.0	81	0	190
			10-29	430	3	13.0			0.01	0.02		0.02	14		8.2	110	0	170
			11-6		6	11.0			0.02	0.00		0.02	10		8.0	73	0	180
			11-21		12	10.0			0.02	0.04		0.08	15		8.0	79	0	180
			11-27	430	8	9.0			0.02	0.01		0.07	15		8.0	75	0	240
			12-4	430	9	8.5			0.06	0.02		0.09	6		7.9	71	0	160
			12-12	930	10	6.0			0.02	0.04		0.03	4		7.9	73	0	280
			1-10-52		3	3.0			0.02	0.03		0.07	14		8.0	80	0	
			1-15		2	3.0			0.00	0.00		0.13	10		7.9	70	0	
			1-22	91	5	2.0			0.04	0.02		0.03	6		8.1	69	0	240
			1-23		6	2.0			0.03	0.02		0.10	10		8.0	68	0	260
			1-29			1.0												140
			2-5	430		3.0												180
			2-19	230		2.0												78
			4-7			8.0												220
			4-14	3.6		7.0												220
			4-29			10.0												190
			5-13		14	11.0			0.05	0.00		0.07			8.2	60	0	77
			5-19	36		10.0												75
			5-26			11.0												56
			6-19			13.0												94
			7-8	<36		14.0												85
			7-16			16.0												90
			7-29			17.0												100
			8-6			18.0												150
			8-18	240		18.0												120
			9-3			18.0												210
			9-8			16.0												140
			9-17			17.0												130
			9-24			17.0												240
			9-29			17.0												250
		500'	8-21-51		9	19.0	8.3	0.80	0.00		0.06	0.00	10	0.2	8.0	85		
			8-30		2	17.0	9.3	1.0	0.03		0.06	0.05	14	0	8.5	90	3	
			9-6		11	19.0			0.01	0.04	0.05	0.00	8		8.1	86	0	110
			9-12															210
			9-19		13				0.02	0.04		0.03	30		8.2	86	0	260
			9-26		11	16.5			0.02	0.00		0.05	15		8.2	88	0	190
			10-2		11	17.0							17		7.8	91	0	190
			10-11		1	17.0			0.01	0.00		0.04	9		8.1	91	0	200
			10-17		7	14.0			0.02	0.01		0.02	14		8.1	73	0	160
			10-22		9	13.5			0.02	0.00		0.06	9		8.1	76		230
			10-29		3	13.5			0.01	0.02		0.02	9		8.2	110	0	210
			11-6		3	11.0			0.03	0.00		0.02	11		8.2	70	0	170
			11-21		12	10.0			0.02	0.03		0.07	10		8.0	74	0	250
			11-27		5	9.0			0.02	0.01		0.08	12		8.0	72	0	280
			12-4		12	8.5			0.05	0.02		0.08	11		7.9	70	0	

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River	C-330	500'	12-12-51		24	6.0			0.02	0.03		0.04	9		7.8	71	0	310
above Kennewick			1-10-52		3	3.0			0.00	0.02		0.07	10		8.0	70	0	
Wash. (cont'd)			1-15		7	3.0			0.00	0.00		0.12	10		7.8	68	0	
			1-22		4	2.0			0.04	0.02		0.04	3		8.1	72	0	220
			1-23		5	2.0			0.03	0.02		0.09	9		8.1	68	0	310
			1-29			1.0												140
			2-5			3.0												230
			2-19			2.0												100
			4-7			8.0												270
			4-14			7.0												210
			4-29			10.0												210
			5-13			11.0												100
			5-19			10.0												90
			5-26			11.0												68
			6-19			13.0												93
			7-8			14.0												93
			7-16			16.0												100
			7-29			17.0												160
			8-6			[illegible]												140
			8-18			[illegible]												150
			9-3			16.0												210
			9-8			16.0												170
			9-17			17.0												140
			9-24			17.0												270
			9-29			17.0												320
			11-26			8.0												220
			12-23			6.0												300
			1-12-53			6.0												270
			2-16			4.0												250
			3-24			6.0												
		1,000'	8-21-51		7	19.0	8.8	0.30	0.01		0.09	0.00	8	0.2	8.0	76		
			8-30		2	17.0	9.1	0.30	0.04		0.06	0.04	15	0		85	0	
			9-6		9	18.5	9.5		0.02	0.06	0.03	0.00	10		8.1	83	0	140
			9-12	230	13	17.5	9.4		0.02	0.04		0.04	27		8.2	83	0	200
			9-19	430	7	18.5			0.00	0.03		0.04	33		8.2	80	0	270
			9-26	930	10	16.5			0.02	0.00		0.04	13		8.1	93	0	250
			10-2	230	3	17.0							11		7.7	79	0	200
			10-11		[illegible]	17.0			0.03	0.00		0.06	7		8.1	81	0	220
			10-17	230	4	14.0			0.02	0.01		0.01	9		8.1	69	0	180
			10-22	750	6	13.5			0.05	0.00		0.06	11		8.1	75	0	270
			10-29	930	1	13.5			0.01	0.02		0.04	7		8.2	100	0	250
			11-6		3	11.0			0.02	0.00		0.05	13		8.2	65	0	190
			11-21		13	10.0			0.02	0.02		0.07	10		8.0	68	0	260
			11-27	430	11	9.0			0.02	0.01		0.06	13		8.0	73	0	310
			12-4	230	12	8.5			0.06	0.02		0.08	6		8.0	67	0	210
			12-12	230	10	6.0			0.02	0.03		0.02	9		7.9	67	0	350
			1-10-52		3	3.0			0.01	0.02		0.14	4		8.0	65	0	
			1-15		3	3.0			0.00	0.00		0.10	9		7.8	72	0	
			1-22	150	4	2.0			0.03	0.01		0.01	10		8.1	69	0	300
			1-23		7	2.0			0.02	0.02		0.10	14		8.0	68	0	320
			1-29			1.0												190
			2-5			3.0												270
			2-19	230		2.0												130
			3-3		<7		13.6											
			3-17		9		13.0											
			4-7			8.0												290
			4-8		8		12.0											
			4-14	<3.6		7.0												230
			4-29			10.0												200
			5-5		22		11.2											
			5-13		12	11.0				0.00		0.05			8.2	57	0	100
			5-19			10.0												80
			5-26			11.0												64
			6-9		10		9.4											
			6-19			13.0												100
			7-8	<36		14.0												87
			7-16			16.0												100

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River	C-330	1,000'	7-29-52			17.0												160
above Kennewick			8-5		<7		8.9											
Wash. (cont'd)			8-6			18.0												120
			8-18	240		18.0												140
			9-3			18.0												240
			9-8		<7		9.8											
			9-17			16.0												170
			9-24			17.0												240
			9-29			17.0												320
			11-26			8.0												240
			12-23			6.0												320
			1-12-53			6.0												310
			2-16			4.0												290
		1,500'	8-21-51		5	19.0	8.8	1.2	0.01		0.05	0.00	10	0.2	8.0	74		
			8-30		2	17.0	9.3	0.30	0.03		0.06	0.04	11	0.0	8.4	80	0	
			9-6		9	18.5			0.02	0.04	0.02	0.00	8		8.1	84	0	160
			9-12		10	17.5			0.02	0.04		0.01	22		8.2	82	0	200
			9-19															190
			9-26		7	16.5			0.02	0.00		0.04	13		8.1	80		260
			10-2		11	17.0							16		7.8	77	0	220
			10-11		3	17.0			0.01	0.00		0.02	4		8.1	85	0	220
			10-17		6	14.0			0.02	0.01		0.03	11		8.1	67	0	120
			10-22		3	13.5			0.02	0.00		0.04	8		8.1	70	0	290
			10-29		3	13.5			0.01	0.01		0.02	8		7.9	81	0	240
			11-6		3	11.0			0.02	0.00		0.01	11		8.2	65	0	210
			11-21		7	10.0			0.01	0.03		0.07	11		8.0	68	0	310
			11-27		8	9.0			0.02	0.01		0.05	9		8.0	65	0	360
			12-4		7	8.5			0.05	0.02		0.08	4		7.9	67	0	190
			12-12		9	6.0			0.02	0.03		0.03	10		7.9	66	0	370
			1-10-52		3	3.0			0.03	0.03		0.19	5		7.9	65	0	
			1-15		2	3.0			0.00	0.00		0.07	7		7.8	70	0	
			1-22		3	2.0			0.02	0.01		0.02	7		8.2	64	0	280
			1-23		5	2.0			0.03	0.02		0.07	10		8.0	67	0	290
			1-29			1.0												210
			2-5			3.0												290
			2-19			2.0												98
			4-7			8.0												300
			4-14			7.0												250
			4-29			10.0												250
			5-13			11.0												72
			5-19			10.0												67
			5-26			11.0												54
			6-19			13.0												90
			7-8			14.0												83
			7-16			16.0												100
			7-29			17.0												180
			8-6			17.0												96
			8-18			17.0												170
			9-3			17.0												230
			9-8			16.0												200
			9-17			17.0												180
			9-24			17.0												300
			9-29			17.0												340
			11-26			8.0												300
			12-23			6.0												270
			1-12-53			6.0												370
			2-16			4.0												410
		2,000'	8-21-51		5	19.0	8.9	0.50	0.00		0.04	0.01	8	0.2	8.1	77		
			8-30		2	17.0	9.3	0.30	0.04		0.05	0.02	11	0.0	8.3	80	0	
			9-6		7	18.5			0.02	0.04	0.02	0.02	6		8.1	85	0	150
			9-12	36	13	17.5			0.02	0.04		0.01	27		8.2	78	0	190
			9-19	91														250
			9-26	430	8	16.5			0.01	0.00		0.03	14		8.2	76	0	270
			10-2	210	6	17.0							16		7.7	75	0	180
			10-11		3	17.0			0.01	0.00		0.01	8		8.1	80	0	190
			10-17	91	6	14.0			0.02	0.00		0.01	8		8.1	64	0	200

(1) Facing Upstream

Table B-1 SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} μc/ml Gross Beta
Columbia River	C-330	2,000'	10-22-51	210	9	13.5			0.05	0.00		0.08	11		8.1	68	0	280
above Kennewick			10-29	230	3	13.5			0.02	0.01		0.00	4		7.9	85	0	200
Wash. (cont'd)			11-6		3	11.0			0.02	0.00		0.00	12		8.1	65	0	200
			11-21		8	10.0			0.02	0.02		0.06	12		8.0	68	0	280
			11-27	230	3	9.0			0.02	0.01		0.05	13		8.0	67	0	290
			12-4	230		8.5			0.05	0.01		0.06	6		7.9	68	0	140
			12-12	230	7	6.0			0.02	0.03		0.02	7		7.9	69	0	330
			1-10-52		5	3.0			0.00	0.02		0.12	4		8.0	64	0	
			1-15		3	3.0			0.00	0.00		0.10	6		7.9	69	0	
			1-22	30	3	2.0			0.04	0.02		0.01	6		8.1	66	0	270
			1-23		4	2.0			0.03	0.02		0.09	11		8.0	67	0	330
			1-29			1.0												150
			2-5	4,600		3.0												250
			2-19	<36		2.0												100
			4-7			8.0												258
			4-14	2,000		7.0												160
			4-29			10.0												250
			5-13		12	11.0			0.04	0.02		0.04			8.1	55	0	69
			5-19	150		10.0												70
			5-26			11.0												50
			6-19			13.0												68
			7-8	<16		14.0												69
			7-16			16.0												84
			7-29			17.0												150
			8-6			17.0												230
			8-18	93		17.0												150
			9-3			17.0												230
			9-8			16.0												220
			9-17			17.0												170
			9-24			17.0												310
			9-29			17.0												330
			11-26			8.0												290
			12-23			6.0												340
			1-8-53			6.0												350
			2-16			4.0												390
Columbia River	C-326	Surf.	2-19-52									0.03						
below Pasco, Wash.		Comp.	3-3			3.0									8.2	70		
			3-17			4.0									8.0	70		
			4-8			7.0									8.0	71		
			5-5			10.0									8.1	74		
			6-9			13.5									8.1	60		
			6-30		3				0.02	0.00		0.04	12		8.1	55	0	
			7-7		11				0.05	0.00		0.02			8.1	58	0	
			7-15			17.0										57		
			8-5			18.0									8.2	59		
			9-8			18.0									8.2	62		
			10-8			17.5									8.2	63		
			11-4			14.0									8.2	66		
			12-17			8.5									8.0	69		
		10'-20'	1-21-52		<7	3.0	13.1								7.9	72		
			2-4		23	4.0	12.8								7.9	69		
			2-18		<7	3.0	14.2								8.0	70		
			4-21		9	10.0	11.3								8.0	75		
		200'	8-21-51		8	19.0	8.6	0.00	0.00		0.09	0.02	8	0.6	8.2	76		
			8-31		3	17.0	9.6	0.50	0.02		0.06	0.04	8	2.0	8.4	87	0	
			9-10	930	13	19.0	9.3		0.03	0.02		0.01	30		8.4	80	2	170
			9-20		7	17.5			0.01	0.00		0.02	19		8.4	86	4	150
			9-27		16	16.0			0.04	0.00		0.04	17		8.4	90	0	170
			10-1	2,400	7	17.0			0.01	0.01			4		8.1	79	0	140
			10-16	1,500	4	14.0			0.02	0.02		0.06	14		8.0	66	0	150
			10-25		15	13.5			0.02	0.00		0.04	12		8.0	68	0	210
			10-30	930	3	13.0			0.02	0.03		0.07	14		8.0	78	0	200
			11-5	930	6	11.5			0.02	0.01		0.04	17		8.1	74	0	120
			11-26	430	17	9.0			0.04	0.01		0.08	12		8.0	68	0	130
			12-4	2,400	10	8.5			0.06	0.02		0.05	13		7.9	71	0	160

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River	C-326	200'	12-10-51	91	11	6.0			0.09	0.01		0.03	12		7.9	77	0	160
below Pasco, Wash.			1-8-52		3	3.0			0.02	0.01		0.11	4		8.0	70	0	
			1-15		4	3.0			0.00	0.00		0.15	11		7.8	70	0	
			1-22	150	5	2.0			0.03	0.01		0.07	10		8.0	70	0	180
			1-29			1.0												140
			2-5	230		3.0												240
			2-13			3.0												260
			2-19	1,500		2.0												81
			3-18			4.0												250
			4-9			6.0												110
			4-16			10.0												190
			5-1			9.0												190
			5-6	430		10.0												120
			5-14			10.0												69
			5-19	230		10.0												67
			5-26			11.0												6[illegible]
			6-17	930		13.0												4[illegible]
			6-23	430		13.0												69
			6-30			14.0												63
			7-8	91		14.0												68
			7-14			15.0												88
			7-31			18.0												98
			8-5			18.0												130
			8-18	1,500		18.0												97
			9-2			17.0												210
			9-8			16.0												180
			9-24			17.0												260
			9-29			17.0												280
			11-26			8.0												290
			12-23			6.0												320
			1-12-53			6.0												310
			2-3															290
			3-24			6.0												290
		500'	8-21-51		5	19.0	8.8	0.50	0.02		0.09	0.00	10	0.6	8.2	74		
			8-31		3	17.0	8.5	0.70	0.01	0.00	0.05	0.08	8	0.3	8.3	82	0	
			9-10		9	19.0			0.03	0.03		0.00	22		8.3	77	0	210
			9-20		8	17.5			0.01	0.00		0.02	19		8.3	82	0	210
			9-27		10	16.0			0.02			0.04	12		8.3	88	0	180
			10-1		7	17.0			0.01	0.01			12		8.0	78	0	170
			10-16		7	14.0			0.02	0.01		0.06	10		8.2	65	0	190
			10-25		5	13.5			0.02	0.00		0.02	5		8.1	85	0	190
			10-30		6	13.0			0.01	0.01		0.07	8		8.0	69	0	250
			11-5		7	11.5			0.02	0.01		0.04	18		8.1	68	0	150
			11-26		11	9.0			0.03	0.01		0.04	10		8.0	69	0	180
			12-4		14	8.5			0.05	0.02		0.05	12		7.9	69	0	190
			12-10		6	6.0			0.09	0.01		0.03	10		7.9	73	0	270
			1-8-52		3	3.0			0.04	0.02		0.10	4		8.1	67	0	
			1-15		3	3.0			0.06	0.00		0.08	6		7.8	70	0	
			1-22		4	2.0			0.05	0.01		0.03	14		8.0	65	0	240
			1-29			1.0												140
			2-5			3.0												160
			2-13			3.0												320
			2-19			2.0												90
			3-18			4.0												130
			4-9			6.0												150
			4-16			10.0												260
			5-1			9.0												210
			5-6			10.0												110
			5-14			10.0												66
			5-19			10.0												76
			5-26			11.0												66
			6-17			12.0												67
			6-2[illegible]			13.0												97
			6-30			14.0												100
			7-8			14.0												92
			7-14			15.0												92
			7-31			18.0												96

(1) Facing Upstream

Table B-1 SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp. °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River	C-326	500'	8-5-52			18.0												130
below Pasco, Wash.			8-18			18.0												150
(cont'd)			9-2			17.0												210
			9-8			16.0												160
			9-24			17.0												270
			9-29			17.0												300
			11-26			8.0												270
			12-23			6.0												330
			1-12-53			6.0												280
			2-3															290
			3-24			6.0												300
		1,500'	8-21-51			19.0	8.6	0.20	0.00		0.08	0.01	8	0.3	8.0	74		
			8-31		2	17.0	9.4	0.40	0.01		0.06	0.01	3	0.3	8.2	77	0	
			9-10	750	11	19.0	9.4		0.05	0.01		0.02	25		8.3	77	0	200
			9-20		4	17.5			0.02	0.00		0.02	17		8.3	85	0	200
			9-27		8	16.0			0.02	0.00		0.04	15		8.2	83	0	200
			10-1	430	6	17.0			0.01	0.01			13		8.0	80	0	170
			10-16	430	6	14.0			0.04	0.01		0.07	18		8.2	89	0	180
			10-25		4	13.5			0.01	0.00		0.03	7		8.0	84	0	90
			10-30		3	13.0			0.00	0.01		0.06	13		7.9	68	0	260
			11-5	91	5	11.5			0.03	0.01		0.04	16		8.2	70	0	150
			11-26	930	7	9.0			0.04	0.01		0.05	13		8.0	67	0	190
			12-4	930	6	8.5			0.06	0.01		0.04	10		7.9	66	0	210
			12-10	150	4	6.0			0.09	0.03		0.03	13		7.8	74	0	370
			1-8-52		5	3.0			0.01	0.02		0.10	6		8.0	66	0	
			1-15		2	3.0			0.00	0.00		0.08	4		7.8	65	0	
			1-22	210	3	2.0			0.03	0.01		0.04	4		8.1	66	0	260
			1-29			1.0												140
			2-5	1,200		3.0												210
			2-13			3.0												290
			2-19	230		2.0												84
			3-3		<7		13.7											
			3-17		8		12.8											
			3-18			4.0												260
			4-8		8		11.8											
			4-9			6.0												150
			4-16			10.0												260
			5-1			8.0												210
			5-5		19		11.4											
			5-6			10.0												100
			5-14			10.0												70
			5-19	91		10.0												68
			5-26			11.0												72
			6-9		7		10.3											
			6-17	91		12.0												81
			6-23	73		13.0												100
			6-30			14.0												110
			7-8	<36		14.0												86
			7-14			15.0												90
			7-15		<7		9.7											
			7-31			18.0												94
			8-5		<7	18.0	9.1											140
			8-18	43		18.0												140
			9-2			17.0												210
			9-8		<7	18.0	9.6											180
			9-24			17.0												240
			9-29			17.0												270
			10-8		<7		9.0											
			11-4		<7		9.5											
			11-26			8.0												290
			12-17		<7		10.0											
			12-23			6.0												320
			1-12-53			6.0												290
			2-3															290
			3-24			6.0												330

(1) Facing Upstream

Table B-1 SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mile-age Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp. °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River	C-326	2,200'	8-21-51		5	19.0	8.4	0.10	0.00		0.06	0.00	8	0.2	8.0	74		
below Pasco, Wash.			8-31		2	17.0	9.6	1.2	0.01		0.03	0.00	3	0.0	8.3	77	0	
(cont'd)			9-10		9	19.0			0.03	0.01		0.01	22		8.3	75	0	190
			9-20		6	17.5			0.02	0.00		0.02	17		8.3	80	0	210
			9-27		11	16.0			0.02	0.00		0.12	15		8.3	80	0	170
			10-1		4	17.0			0.01	0.01			6		8.0	75	0	130
			10-16		22	14.0			0.01	0.01		0.13	26		8.3	100	0	150
			10-25		4	13.5			0.02	0.00		0.02	3		8.0	85	0	200
			10-30		3	13.0			0.00	0.01		0.06	11		8.0	68	0	240
			11-5		4	11.5			0.02	0.01		0.04	15		8.2	65	0	150
			11-26		5	9.0			0.03	0.01		0.04	10		8.0	68	0	260
			12-4		7	8.5			0.06	0.01		0.05	10		8.0	65	0	170
			12-10		6	6.0			0.09	0.02		0.02	11		7.9	67	0	260
			1-8-52		6	3.0			0.03	0.02		0.24	10			67	0	
			1-15		3	3.0			0.00	0.00		0.10	4		7.9	66	0	
			1-22		4	2.0			0.02	0.01		0.02	3		8.1	66	0	260
			1-29			1.0												160
			2-5			3.0												180
			2-13			3.0												270
			2-19			2.0												98
			3-18			5.0												320
			4-9			6.0												140
			4-16			10.0												250
			5-1			8.0												230
			5-6			10.0												100
			5-14			10.0												54
			5-19			10.0												68
			5-26			11.0												61
			6-17			12.0												89
			6-23			13.0												100
			6-30			14.0												94
			7-8			14.0												76
			7-14			15.0												110
			7-31			18.0												150
			8-5			18.0												110
			8-18			18.0												120
			9-2			17.0												190
			9-8			16.0												180
			9-24			17.0												310
			9-29			17.0												290
			11-26			8.0												310
			12-23			6.0												350
			1-12-53			6.0												320
			2-3															480
			3-24			6.0												300
		2,500'	8-21-51		3	19.0	8.9	0.70	0.00		0.07	0.00	8	0.2	8.0	76		
			8-31		2	17.0	9.6	0.40	0.01		0.06	0.00	8	0.0	8.3	76	0	
			9-10	4,600		19.0	9.1											
			9-20		15	17.5			0.06	0.00		0.01	40		8.3	80	0	200
			9-27		8	16.0			0.02	0.00		0.04	15		8.1	79	0	220
			10-1	2,400	6	17.0			0.01	0.01			8		8.0	76	0	170
			10-16	4,600	21	14.0			0.00	0.03		0.06	44		8.4	130	0	130
			10-25		3	13.5			0.02	0.00		0.03	6		8.2	84	0	170
			10-30	4,600	3	13.0			0.01	0.02		0.05	11		8.0	65	0	240
			11-5	4,600	5	11.5			0.02	0.04		0.03	19		8.2	65	0	76
			11-26	4,600	7	9.0			0.04	0.02		0.06	15		8.0	64	0	
			12-4	930	13	8.5			0.07	0.02		0.07	10		7.9	67	0	170
			12-10	2,400	4	6.0			0.10	0.02		0.03	12		8.0	69	0	250
			1-8-52		5	3.0			0.02	0.01		0.12	4			65	0	
			1-15		5	3.0			0.00	0.00		0.10	3		7.9	67	0	
			1-22	930	5	2.0			0.03	0.01		0.01	4		8.0	65	0	210
			1-29			1.0												120
			2-5	230		3.0												190
			2-13			3.0												250
			2-19	390		2.0												130
			3-18			6.0												220
			4-9			6.0												110

(1) Facing Upstream

Table B-1 SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm P'	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River	C-326	2,500'	4-16-52			10.0												180
below Pasco, Wash.			5-1			9.0												200
(cont'd)			5-6	4,600		10.0												79
			5-14			10.0												56
			5-19	930		10.0												63
			5-26			11.0												51
			6-17	230		12.0												75
			6-23	91		13.0												95
			6-30			14.0												60
			7-8	1,500		14.0												63
			7-14			15.0												83
			7-31			18.0												100
			8-5			18.0												110
			8-18	2,400		18.0												150
			9-2			17.0												200
			9-8			16.0												190
			9-24			17.0												240
			9-29			17.0												280
			11-26			8.0												290
			12-23			6.0												340
			3-26-53		<7	7.0	11.0								8.1	68		
Columbia River	C-316	Surf.	1-30-52						0.03	0.01		0.03	9		7.8	89	0	
above Walla Walla		Comp	2-20									0.09						
River			3-5			3.5									8.2	79		
			3-19			6.0									8.1	78	0	
			4-23			10.0									8.0	63		
			5-7			10.0									7.9	57		
			6-30										11					
			7-31										12					
			8-13			21.0									8.2	72		
			9-24		8				0.01	0.01	0.07	0.04			8.3	70	4	
			11-17			11.5									8.0	65		
		10'-20'	1-23-52		<7	3.0	14.0								8.3	68		
			2-6		10	5.0									8.2	72		
			4-23		9													
			5-7		26													
			8-13		7													
		400'	8-15-51		6	19.0	10.9		0.01		0.12	0.10	13	0.0	8.4	75		
			8-22		8	19.0	8.9	0.50	0.04	0.04	0.04	0.00	10	0.2	8.2	80	2	
			8-29		4	17.5	9.7	1.5	0.03	0.03	0.00	0.04	17	0.0		80	2	
			9-12	430	11	17.5	9.5	1.6	0.02	0.01		0.03	21		8.2	86	0	160
			9-20		8	17.5			0.01	0.00		0.00	18		8.2	83	0	190
			9-27		15	16.5			0.03	0.00		0.02	12		8.4	84	0	130
			10-2	930	4	17.0							10		7.8	79	0	140
			10-16	4,600	6	14.5			0.02	0.01		0.06	14		8.0	66	0	110
			10-25		4	13.5			0.01	0.00		0.04	11		7.8	74	0	180
			10-30	930	0	13.0			0.01	0.00		0.05	12		8.0	69	0	190
			11-5	2,400	7	11.5			0.02	0.01		0.11	18		8.2	66	0	97
			11-26	4,600	5	8.5			0.04	0.01		0.10	10		7.9	67	0	220
			12-3	2,400	12	9.0			0.07	0.01		0.06	9		8.2	75	0	5
			12-10	230		6.0			0.00	0.01		0.06	12		7.8	73	0	190
			1-8-52		3	3.0			0.00	0.01		0.12	[illegible]		8.0	68	0	
			1-14		3	4.0			0.00	0.00		0.14	3		8.1	70	0	
			1-21		7	3.0			0.03	0.02		0.08	2		8.1	68	0	140
			1-30			2.0												150
			2-6			2.0												
			2-13			3.0												230
			2-20			2.0												120
			3-18			4.0												190
			3-31			8.0												170
			4-7			8.0												220
			4-9			6.0												110
			4-16			8.0												210
			5-1			9.0												160
			5-6		22	10.0			0.07	0.00		0.00			7.8	62	0	94

(1) Facing Upstream

Table B-1 SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River	C-316	400'	5-20-52			10.0												69
above Walla Walla			5-27			10.0												67
River (cont'd)			6-16		7	13.0			0.14	0.00		0.01			7.9	54	0	69
			6-30		5	13.0			0.03	0.00		0.04			8.1	68	0	61
			7-7		6	14.0			0.04	0.00		0.04			7.9	62	0	61
			7-14			15.0												60
			7-31		2	18.0			0.02	0.00		0.02			8.5	63	2	110
			8-5			18.0												100
			8-18		5	18.0			0.00	0.00		0.05			8.3	49	2	86
			9-2			17.0												180
			9-24			17.0												200
			9-30			17.0												260
			11-13			10.0												210
			12-31			5.0												330
			1-26-53			6.0												230
			2-24			5.0												250
		1,000'	8-15-51		5	19.0	10.8	0.70	0.01		0.11	0.02	13	0.0	8.3	72	0	
			8-22		6	19.0	8.8	0.40	0.04	0.03	0.02	0.00	10	0.2	8.0	78	4	
			8-29		3	17.5	9.6	1.0	0.02	0.02	0.01	0.13	13	0.0		76	0	
			9-12		11	17.5			0.02	0.02		0.02	23		8.2	86	0	160
			9-20		6	17.5			0.02	0.00		0.01	18		8.4	82	0	190
			9-27		17	16.5			0.03	0.00		0.04	13		8.3	82	0	160
			10-2		7	17.0							17		7.8	79	0	140
			10-16		7	14.5			0.02	0.01		0.06	10		8.2	65	0	110
			10-25		9	13.5			0.01	0.00		0.04	9		7.9	66	0	150
			10-30		3	13.0			0.00	0.00		0.05	15		8.0	68	0	190
			11-5		3	11.5			0.01	0.01		0.04	10		8.2	70	0	130
			11-26		3	8.5			0.04	0.01		0.04	12		8.0	74	0	100
			12-3		12	8.5			0.03	0.01		0.08	6		8.2	80	0	72
			12-10		18	6.0			0.00	0.01		0.05	10		7.8	70	0	190
			1-8-52		2	3.0			0.02	0.02		0.15	4		8.1			
			1-14		8	4.0			0.02	0.00		0.12	3		8.2	73	0	
			1-21		7	3.0			0.05	0.02		0.08			8.1	68	0	150
			1-30			2.0												140
			2-6			2.0												
			2-13			3.0												220
			2-20			2.0												140
			3-5				13.2											
			3-18			4.0												190
			3-19				12.7											
			3-31			8.0												160
			4-7			8.0												230
			4-9			6.0												95
			4-16			8.0												180
			4-23				10.7											
			5-1			10.0												110
			5-6		22	10.0			0.03	0.01		0.01			7.8	62	0	16
			5-20			10.0												76
			5-27			11.0												60
			6-16		11	13.0			0.18	0.00		0.03			7.9	55	0	70
			6-30		5	13.0			0.05	0.00		0.02			8.0	58	0	70
			7-7		6	14.0			0.04	0.00		0.04			8.0	59	0	68
			7-14			15.0												60
			7-31		2	18.0			0.02	0.00		0.02			8.5	60	2	120
			8-5			18.0												95
			8-13				9.2											
			8-18		5	18.0			0.00	0.00		0.02			8.4	62	0	100
			9-2			17.0												150
			9-24			17.0												220
			9-30			17.0												240
			11-13			10.0												210
			11-17		<7		9.8											
			12-31			5.0												390
			1-26-53			6.0												280
			2-24			5.0												290
		1,500'	8-5-51		5	19.0	10.4		0.02		0.09	0.02	16	0.0	8.4	70		

(1) Facing Upstream

Table B-1 SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River	C-316	1,500'	8-22-51		8	19.0	8.8	0.60	0.03	0.04	0.08	0.00	9	0.2	8.1	81	2	
above Walla Walla			8-29		4	17.5	9.3	0.40	0.02	0.03	0.04	0.02	10	0.0		72	0	
River (cont'd)			9-12	230	14	17.5			0.01	0.02		0.02	27		8.2	80	0	160
			9-20		9	17.5			0.02	0.00		0.02	32		8.4	97	0	150
			9-27		19	16.5			0.04	0.00		0.04	14		8.3	91	0	140
			10-2	230	8	17.0							16		7.9	87	0	130
			10-16	750	6	14.5			0.04	0.02		0.07	18		8.2	89	0	150
			10-25		7	13.0			0.02	0.00		0.04	12		8.0	75	0	160
			10-30	1,500	7	12.0			0.03	0.02		0.08	16		7.9	71	0	140
			11-5	91	3	10.5			0.02	0.02		0.04	17		8.2	76	0	110
			11-26	1,500	5	7.5			0.04	0.03		0.03	17		8.0	91	0	130
			12-3	1,500	27	6.5			0.10	0.02		0.01	31		8.3	95	0	20
			12-10	430	12	5.0			0.00	0.02		0.19	15		7.9	74	0	170
			1-8-52		2	2.0			0.04	0.02		0.10	4		8.1	79	0	
			1-14		5	3.0			0.00	0.00		0.13	3		8.1	78	0	
			1-21		10	3.0			0.04	0.03		0.09			8.2	76	0	160
			1-30			2.0												140
			2-6			2.0												
			2-13			3.0												160
			2-20			2.0												96
			3-18			4.0												150
			3-31			8.0												14
			4-7			8.5												50
			4-9			8.0												7
			4-16			10.0												240
			5-1			10.0												28
			5-6		35	10.0			0.03	0.00		0.01			7.8	49	0	16
			5-20			11.0												14
			5-27			13.0												14
			6-16		14	13.0			0.14	0.00		0.20			7.9	57	0	68
			6-30		7	13.0			0.04	0.00		0.05			8.0	58	0	86
			7-7		6	14.0			0.05	0.01		0.09			8.0	60	0	57
			7-14			16.0												75
			7-31		2	18.0			0.02	0.00		0.01			8.6	61	2	100
			8-5			18.0												93
			8-18		8	18.0			0.00	0.01		0.04			8.5	55	2	120
			9-2			17.0												190
			9-24			17.0												220
			9-30			17.0												180
			11-13			9.0												150
			12-11			3.0												340
			1-26-53			5.0												140
			2-24			5.0												200
		1,800'	8-15-51		7	20.5	10.2		0.03		0.13	0.01	20	0		99		
			8-22		9	20.5	8.0	1.0	0.06	0.08	0.04	0.00	9	2	8.4	120	10	
			8-29		7	18.5	9.5	1.5	0.05	0.07	0.10	0.07	38	10		120	5	
			9-12		11	17.5			0.03	0.05		0.04	32			110	0	120
			9-20		9	17.5			0.04	0.00		0.01	29		8.6	120	5	100
			9-25		15	16.5			0.02	0.01		0.00	27		8.3	130	0	81
			9-27		11	16.5			0.01	0.00		0.09	42		8.2	110	0	120
			10-2		11	17.0							30		8.0	51	5	58
			10-16		22	14.5			0.01	0.01		0.13	26		8.3	100	0	150
			10-25		20	10.5			0.00	0.00		0.00	19		7.9	99	0	73
			10-30		15	10.5			0.00	0.02		0.12	30		8.0	90	0	75
			11-5		8	7.5			0.04	0.04		0.07	30		8.4	100	0	47
			11-26		7	6.0			0.06	0.04		0.04	38		8.1	110	0	56
			12-3		43	6.0			0.05	0.01		0.05	31		8.[illegible]	110	0	4
			12-10			3.5			0.10	0.03		0.10	21		7.8	95	0	56
			1-8-52		9	1.0			0.03	0.00		0.10	20		8.1	110	0	
			1-14		22	1.0			0.02	0.00		0.07	6		8.2	120	0	
			1-21		33	2.0			0.06	0.03		0.05			8.2	95	0	39
			1-30			2.0												21
			2-6			1.0												
			2-13			3.0												9
			2-20			2.0												3
			3-18			5.0												62
			3-31			8.0												<1

(1) Facing Upstream

Table B-1 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River	C-316	1,800'	4-7-52			9.5												2
Above Walla Walla			4-9			8.0												<1
River (cont'd)			4-16			10.0												<1
			5-1			10.0												2
			5-6		43	10.0			0.03	0.01		0.01			7.8	43	0	2
			5-20			12.0												3
			5-27			13.0												<1
			6-16		16	13.0			0.20	0.00		0.07			7.9	59	0	24
			6-30		20	15.0			0.10	0.00		0.11			8.1	57	0	32
			7-7		15	17.0			0.07	0.01		0.16			8.3	70	5	13
			7-14			20.0												20
			7-31		2	20.0			0.02	0.00		0.03			8.8	72	5	80
			8-5			20.0												69
			8-18		10	20.0			0.50	0.00		0.06			8.5	62	2	62
			9-2			17.0												91
			9-24			17.0												130
			9-30			17.0												110
			11-13			8.0												63
			12-31			3.0												130
			1-26-53			4.0												31
			2-24			4.0												27
		2,100'	8-15-51		11	20.5	10.0	2.1	0.02		0.05	0.02		0		120		
			8-22		16	22.0	7.7	0.80	0.08	0.09	0.04	0.00		3	8.4	130	9	
			8-29		5	19.0	9.4	1.8	0.06	0.10	0.10	0.08	31	15		140	12	
			9-12	930	21	17.5	9.8	0.70	0.06	0.11		0.04	48			140	0	9
			9-20		8	17.5			0.06	0.00		0.02	45		8.7	140	19	9
			9-25	4,600	20	16.5			0.02	0.03		0.01	52		8.5	170	10	4
			9-27		32	15.5			0.01	0.00		0.00	32					1
			10-2	430	14	17.0							47		8.0	170	6	12
			10-16	430	21	14.5			0.00	0.01		0.06	44		8.4	130	0	45
			10-25		16	9.5			0.02	0.00		0.00	22		8.1	110	0	15
			10-30	430	20	8.5			0.01	0.02		0.12	30		8.1	76	0	12
			11-5	750	7	6.0			0.07	0.01		0.07	45		8.4	120	0	4
			11-26	430	13	4.5			0.08	0.06		0.04	33		8.2	130	0	7
			12-3	2,400	43	6.0			0.05	0.02		0.07	27		8.1	110	0	>9
			12-10	4,600		2.0			0.08	0.02		0.16	27		7.9	110	0	1
			1-8-52		13	0.0			0.10	0.00		0.05	27		8.2	120	0	
			1-14		25	0.0			0.04	0.00		0.10			8.3	130	0	
			1-21		24	2.0			0.06	0.02		0.03			8.2	110	0	<1
			1-30			2.0												3
			2-6			1.0												
			2-13			3.0												1
			2-20			2.0												<1
			3-18			6.0												2
			3-31			8.0												<1
			4-7			10.0												<1
			4-9			8.0												<1
			4-16			10.0												<1
			5-1			10.0												2
			5-6		27	10.0			0.04	0.02		0.01			7.8	44	0	<1
			5-20			12.0												3
			5-27			13.0												2
			6-16		24	13.0			0.18	0.00		0.18			7.9	56	0	7
			6-30		34	16.0			0.10	0.01		0.07			8.2	60	0	2
			7-7		16	18.0			0.07	0.00		0.09			8.3	76	4	2
			7-14			22.0												6
			7-31		?	23.0			0.04	0.00		0.03			9.0	97	13	6
			8-5			23.0												5
			8-18		21	20.0			0.18	0.01		0.08			8.4	110	9	2
			9-2			19.0												<1
			9-24			17.0												3
			9-30			17.0												<1
			11-13			5.0												4
			12-31			2.0												<1
			1-26-53			4.0												<1
			2-24			4.0												2

(1) Facing Upstream

Table B-1 SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} μc/ml Gross Beta
Columbia River above Walla Walla River (cont'd)	C-316	2,300'	2-6-52		>150	5.0	13.5								8.2	70		
			2-20		20	3.0	12.8								8.1	86		
			4-9		140	9.0	10.8								8.1	57		
			4-23		110													
			5-7		60													
			8-13		90													
Columbia River at Juniper Canyon	C-306	Surf.	2-20-52									0.08						
		Comp.	3-5			3.5									8.2	90		
			3-19			6.0									8.2	89		
			4-23			10.0									7.9	62		
			5-7			10.0									7.9	62		
			6-18			15.0									8.1	55		
			7-9			17.0									8.0	61		
			8-13			21.0									8.1	64		
			10-29			14.0									8.2	97		
			11-17			11.5									8.2	87		
			12-17			8.0									8.0	92		
		10'-20'	2-6-52		120	4.0	13.1								7.9	74		
			6-18		<7													
			7-9		<7													
			8-13		7													
		200'	8-15-51		8	19.5	9.7		0.04		0.16	0.05	12	0.2	8.3	83		
			8-22		5	19.5	8.3	0.70	0.04	0.04	0.04	0.10	12	0.4	8.0	81	2	
			8-29		4	18.0	9.1	0.30		0.03	0.04	0.07	21	3.0		76	2	
			9-5			18.5												82
			9-18	930		18.5			0.04	0.00		0.00	23		8.1	110	0	110
			10-3	1,500	18	16.0							30		8.0	100	0	96
			10-23	290	10	12.0			0.02	0.04		0.14	20		8.2	85	0	120
			10-31	930		12.0			0.04	0.01		0.06	15		8.2	83	0	110
			11-7		9	10.0			0.02	0.00		0.28	16		8.2	87	0	120
			11-14	930	7	9.5			0.02	0.01		0.02	22		8.2	78	0	180
			11-20	4,600	8	8.0			0.02	0.02		0.03	15		8.0	76	0	180
			11-28	430		8.0			0.02	0.03		0.03	14		8.4	89	0	190
			12-11	2,400	9	5.0			0.02	0.02		0.07	7		7.9	72	0	150
			1-14-52		6	2.0			0.00	0.00		0.09	2		8.1	72	0	
			1-21		27	3.0			0.06	0.01		0.09			8.0	71	0	85
			2-12			3.0												150
			2-20			2.0												70
			3-19			5.0												160
			4-8			8.0												110
			5-5			10.0												100
			7-15			17.0												76
			7-30			17.0												110
			11-13			10.0												150
			12-31			4.0												260
			1-26-53			5.0												190
			2-24			5.0												200
		800'	8-15-51		7	19.5	10.0	0.90	0.02		0.12	0.09	12	0.3	8.4	82		
			8-22		5	19.5	8.3	0.70	0.06	0.04	0.14	0.00	14	0.8	8.2	81	3	
			8-29		4	18.0	9.2	1.0	0.02	0.02	0.04		19	3.0		85	0	
			9-5			18.5												56
			9-18			18.5			0.02	0.00		0.02	18		8.2	102	6	110
			10-3	950	21	17.0							32		7.9	100	0	61
			10-23	430	10	12.0			0.03	0.06		0.14	21		8.2	85	0	89
			10-31	430		12.0			0.04	0.01		0.09	21		8.3	83	0	150
			11-7		4	10.0			0.02	0.00		0.18	26		8.1	86	0	80
			11-14	430	8	9.0			0.03	0.01		0.02	27		8.2	88	0	120
			11-20	930	10	7.5			0.04	0.02		0.04	17		8.0	86	0	150
			11-28	930		8.0			0.02	0.03		0.03	20		8.4	93	0	160
			12-11	750	9	5.0			0.00	0.00		0.05	13		7.9	81	0	130
			1-14-52		10	2.0			0.01	0.00		0.14	13		8.1	85	0	
			1-21		>150	3.0			0.03	0.01		0.12			8.0	79	0	36
			2-12			3.0												110
			2-20			2.0												52

(1) Facing Upstream

Table B-1 SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River at	C-306	800'	3-5-52		70	3.5	12.9								8.2	90		
Juniper Canyon			3-19		60	6.0	12.2								8.2	89		100
(cont'd)			4-8			8.0												26
			5-5			10.0												41
			7-15			18.0												61
			9-30			17.0												210
			11-13			9.0												120
			12-31			4.0												230
			1-26-53			5.0												110
			2-24			5.0												150
		1,400'	8-15-51		8	19.5	10.1		0.02		0.17	0.04	14	0.0	8.4	78		
			8-29		7	19.5	8.4	0.70	0.06	0.07	0.1	0.00	14	0.8	8.2	89	5	
			9-5		4	18.0	9.2	1.0	0.03	0.04	0.04	0.07	21	3.0		92	0	85
			9-18		4	18.5	9.2	0.20	0.02	0.00	0.01	0.16	8	2.0	8.2	96	0	74
			10-3	930	15	17.0							27		7.9	110	0	85
			10-23	2,400	11	12.0			0.04	0.06		0.04	21		8.2	89	0	90
			10-31	430		12.0			0.04	0.01		0.08	24		8.2	83	0	150
			11-7		10	10.0			0.02	0.01		0.08	20		8.2	88	0	89
			11-14	2,400	11	9.0			0.04	0.01		0.02	22		8.3	88	0	110
			11-20	930	6	7.5			0.04	0.03		0.05	22		8.1	88	0	150
			11-28	2,400		8.0			0.03	0.04		0.06	21		8.4	91	0	170
			12-13		17	5.0			0.00	0.01		0.07	15		7.8	78	0	100
			1-14-52		9	2.0			0.06	0.00		0.28	1		8.1	88	0	
			1-21		>150	3.0			0.00	0.02		0.07			8.1	76	0	57
			1-23			2.5	13.5								8.2	85		
			2-6		>150	4.0	13.2								7.9	79		
			2-12			3.0												110
			2-20		8	3.5	13.1								8.1	82		55
			3-19			5.0												100
			4-8			8.0												20
			4-23		110		10.7											
			5-5			10.0												33
			5-7		23		10.8											
			6-18				10.3											
			7-9				10.4											
			7-15			18.0												55
			8-13				9.4											
			9-10			17.0												140
			10-29		12		10.3											
			11-13			9.0												
			11-17		<7		9.7											
			12-17		<7		10.5											
			12-31			4.0												230
			1-26-53			5.0												87
			2-24			5.0												140
		2,700'	8-15-51	930	7	20.0	10.4	1.5	0.02		0.10	0.03	12	0.2	8.4	80		
			8-22	430	7	19.5	8.7	0.90	0.06	0.06	0.04	0.01	15	0.7	8.2	89	5	
			8-29		4	18.0	9.0	0.90	0.02	0.04	0.04	0.07	19	2.0		92	3	
			9-5		4	18.5			0.05	0.00	0.00	0.12	9	3.0	8.3	95	0	74
			9-18			18.5			0.04	0.00		0.00	22		8.3	100	15	130
			1-23-52		<7	2.5	13.5								8.2	85		
			2-6		>150	4.0	13.1								7.9	74		
			2-20		80	3.5	13.1								8.1	82		
			4-8			8.0												19
			4-9		120	8.5	10.8								8.1	55		
			5-5			10.0												36
			6-18		15													
			7-9		12													
			7-15			18.0												57
			8-13		40													
Columbia River	C-297	Surf.	2-27-52			4.0									8.2	83		
above McNary Dam		Comp.	3-12			5.0									8.2	89		
			4-23			10.0									7.9	59		
			6-18			14.0									8.0	59		
			7-9			17.0									8.1	67		

(1) Facing Upstream

Table B-1 SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River	C-297	Surf.	9-10-52			17.0									8.1	71		
above McNary Dam		Comp.	10-15			16.5									8.3	92	4	
(cont'd)			11-6			12.0									8.3	89	7	
			12-17			8.0									8.0	90		
			1-7-53			6.0									8.0	97		
		10'-20'	1-30-52		26	3.5	13.1								8.1	78		
			2-13		13	3.0	13.3								8.1	77		
			3-26		20	9.0	11.6								8.1	78		
			4-30		45	10.0	10.6								7.9	58		
			5-14		22	10.0	11.0								7.9	57		
			6-18		9													
			7-9		<7													
			8-6		9	20.0	9.3								8.2	58		
			2-11-53			6.0	11.9								8.1	68		
			3-4			7.0	11.1								8.2	79		
		1,000'	2-27-52		<7		13.1											
			3-12		29		12.5											
			4-23		75		10.6											
			6-18		13		9.9											
			7-9				10.3											
			9-10		11		9.6											
			10-15		10		10.4											
			11-6		9		11.3											
			12-17		<7		10.2											
			1-7-53		<7		10.7											
		1,900'	6-18-52		13													
			7-9		9													
Columbia River at	C-278	Surf.	2-27-52			4.0									8.2	85		
Paterson, Wash.		Comp.	3-12			5.0									8.2	87		
			4-23			10.0									8.0	62		
			5-5		22				0.05	0.01		0.04	11		7.6	54	0	
			5-20										9					
			6-18			14.0									8.1	58		
			7-7		7				0.03	0.00		0.04	12		7.9	60	0	
			7-9			18.0									8.0	63		
			8-6			20.0									8.2	67		
			9-10			17.0									8.1	76		
			9-30		8				0.05	0.03	0.00	0.05	23		8.4	80	4	
			10-15			16.0									8.4	92	8	
			11-6			12.0									8.1	86	2	
			11-13		5				0.03	0.00	0.15	0.08	23		7.9	82	0	
			12-17			8.0									8.0	92		
			12-31		7				0.07	0.00	0.07	0.08			8.0	96	0	
		10'-20'	1-30-52		30	3.5	13.2								7.9	82		
			2-13		20	5.0	13.8								8.2	80		
			3-26		20	9.0	12.2								8.1	87		
			4-30		50	11.5	10.9								7.9	53		
			5-14		22	12.0	11.5								7.9	54		
			6-18		8													
			7-9		<7													
			2-11-53			6.0	11.1								8.0	69		
			3-4			7.0	11.3								8.2	73		
		500'	8-20-51		6	20.5	9.8	1.3	0.00		0.09	0.01	13	3	8.3	89	3	
			8-28		7	22.5	9.8	1.0	0.00	0.04	0.03	0.01	13	2	8.5	91	2	
			9-10	930														
			9-18	230	15	19.5			0.04	0.00		0.00	20		8.2	100	3	70
			10-23	2,400	8	13.5			0.02	0.05		0.20	22		8.2	90	0	76
			10-[illegible]	430		12.0			0.05	0.03		0.07	20		8.0	83	0	88
			11-7		10	10.0			0.01	0.02		0.18	18		8.2	88	0	54
			11-14	430	5	9.0			0.02	0.03		0.02	21		8.2	89	0	92
			11-20	430	5	8.0			0.02	0.02			17		8.1	82	0	110
			11-28	230		8.0			0.01	0.03		0.04	23		8.4	85	0	100

(1) Facing Upstream

Table B-1 SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River at	C-278	500'	12-11-51	430	14	4.5			0.05	0.05		0.14	13		8.0	82	0	89
Paterson, Wash.			2-12-52	290		3.0												61
(cont'd)			3-19			5.0												92
			4-1			8.0												47
			4-8			8.0												45
			4-15	150		10.0												38
			5-5	430		10.0												18
			5-12		23	11.0				0.01		0.03			8.3	54	0	36
			5-20			11.0												27
			7-7			16.0												26
			7-15			18.0												39
			9-30			18.0												99
			11-13			9.0												65
			12-31			4.0												130
			1-26-53			5.0												70
			2-24			5.0												88
			3-11															100
		1,000'	8-20-51		12	20.5	9.5	0.50	0.03		0.04	0.00	11	2	8.3	97	12	
			8-28		7	22.5	9.8	1.0	0.02		0.04	0.06	12	2	8.6	93	4	
			9-10	930	11	19.0	10.3	1.4	0.05	0.04		0.03	40		8.5	99	5	52
			9-18	210	10	19.5			0.02	0.00		0.00	21		8.2	100	4	70
			10-23	930	11	13.5			0.03	0.05		0.18	25		8.2	89	0	72
			10-31	430		12.0			0.03	0.02		0.10	21		8.1	83	0	83
			11-7		7	10.0			0.02			0.22	20		8.2	85	0	56
			11-14	2,400	6	9.0			0.02	0.03		0.02	27		8.2	88	0	78
			11-20	430	3	8.0			0.03	0.03		0.02	15		8.0	85	0	100
			11-28	750		8.0			0.04	0.02		0.03	19		8.4	79	0	120
			12-11	930	14	4.5			0.05	0.05		0.11	12		7.8	82	0	98
			2-12-52	430		3.0												76
			2-27		<7		14.0											
			3-12		28		13.2											
			3-19			5.0												69
			4-1			8.0												47
			4-8			8.0												43
			4-15	150		10.0												38
			4-23		75		11.4											
			5-5	1,500		10.0												42
			5-12		21	11.0				0.01		0.04			8.3	55	0	32
			5-20			11.0												26
			6-18		14		10.3											
			7-7			16.0												24
			7-9				10.9											
			7-15			18.0												39
			8-6		9		9.9											
			9-10		11		11.0											
			9-30			18.0												110
			10-15		10		10.5											
			11-6		9		9.7											
			11-13			8.0												100
			12-17		<7		11.3											
			12-31			4.0												130
			1-26-53															66
			3-11															110
		1,500'	8-20-51		7	20.5	9.0	0.20	0.02		0.08	0.00	13	4	8.4	97	3	
			8-28		7	22.5	10.0	1.2	0.02		0.04	0.09	12	2	8.6	93	5	
			9-10	2,400														
			9-18	210	8	19.5			0.01	0.00		0.00	26		8.2	100	6	97
			10-23	930	10	13.5			0.01	0.08		0.14	25		8.2	89	0	81
			10-31	930		12.0			0.05	0.02		0.10	22		8.2	84	0	88
			11-7		5	10.0			0.03	0.00		0.30	20		8.2	88	0	57
			11-14	2,400	5	9.0			0.03	0.01		0.02	30		8.3	89	0	92
			11-20	930	7	8.0			0.02	0.02		0.04	22		8.0	83	0	90
			11-28	430		8.0			0.04	0.02		0.04	20		8.4	90	0	120
			12-11		15	4.5			0.05	0.05		0.10	15		7.8	80	0	80
			2-12-52	2,400		3.0												60
			3-19			5.0												80

(1) Facing Upstream

Table B-1 SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp. °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Columbia River at Paterson, Wash. (cont'd)	C-278	1,500'	4-1-52			8.0												42
			4-8			8.0												28
			4-15	>2,400		10.0												30
			5-5	930		10.0												33
			5-12		29	11.0				0.02		0.07			8.2	49	0	10
			5-20			11.0												26
			6-18		15													
			7-7			16.0												21
			7-9		12													
			7-15			18.0												39
			9-30			18.0												91
			11-13			9.0												100
			12-31			4.0												140
			1-26-53															58
			2-24			5.0												120
TRIBUTARIES																		
Yakima River at Kiona, Wash.	CY-364	Mid.	8-14-51		13	22.0	9.0	0.20	0.02		0.26	0.08	15	0.6	8.4	180		
			8-16		11	20.5	8.3	2.4	0.07		0.22	0.22	16	6.0	8.1	170		
			8-20		12	21.5	6.4	1.9	0.09		[illegible]	0.00	15	5.0	8.0	180	10	
			8-23		11	19.0	7.1	0.90	0.04	0.07	0.12	0.08	15	5.0	8.2	140	0	
			8-30		5	17.0	8.8	2.2	0.01	0.05	0.22	0.00	28	6.0	8.6	180	11	
			9-5		5	19.5	9.6	0.60	0.08	0.08	0.07	0.20	12	6.0	8.0	170	0	
			9-18	930	12	20.5	10.8	1.3	0.04	0.00		0.00	22		8.2	180	0	<1
Yakima River at Enterprise, Wash.	CY-343	Mid.	8-14-51		18	21.0	9.7	3.8	0.04	0.00	0.03	0.02	15	0		180		
			8-16		15	21.0	8.3	3.2	0.06		0.12	0.14	16	6	8.4	180		
			8-23		13	19.5	7.4	1.5	0.04	0.08	0.07	0.07	17	5	8.4	140	8	
			8-30		6	16.5	8.7	1.4	0.01	0.05	0.09	0.01	21	5	8.7	180	12	
			9-5		5	19.5	9.1		0.06	0.08	0.01	0.16	12	5	8.2	170	0	
			11-13	930	5	7.5			0.04	0.05		0.02			8.2	120	0	<1
			12-5	2,100	12	6.0			0.02	0.02		0.01	13		8.2	100	0	
			1-7-52		12	0.0			0.06	0.04		0.07	9		7.8	120	0	
			1-9		15	0.0			0.06	0.00		0.18	20		8.1	110	0	
			1-16		5	1.0			0.03	0.00		0.18	2		8.1	120	0	
			1-30		<7	2.0	13.0								8.0	100		
			2-4	11,000	41	2.0			0.02	0.05	0.14	0.03	13		7.6	81	0	<1
			3-26		<7	12.0	11.7								8.2	120		
			4-30		10	12.5	10.0								8.0	75		
			6-23		11		9.8								8.5	140	9	
			9-9		27	17.0	9.9								8.4	140	8	
			11-6		20	10.0	12.0								8.5	150	17	
Yakima River at Richland Highway Bridge	CY-339	Mid.	8-16-51		15	21.0	7.9	3.8	0.07		0.09	0.16	16	6	8.4	180		
			8-23		10	19.5	7.5	1.5	0.04	0.10	0.04	0.06	18	6	8.3	140	4	
			8-30		6	16.5	8.1	1.3	0.01	0.05	0.07	0.00	25	5	8.7	180	11	
			9-5		4	19.5	8.9		0.05	0.07	0.08	0.19	14	5	8.2	170	0	
			9-25	2,400	14	16.5	9.4	1.7	0.01	0.00	0.00	0.02	[illegible]		8.2	190	6	<1
			11-7		7				0.04	0.02		0.11	15		8.2	120	0	4
			11-13	930	5	7.5			0.04	0.03		0.02			8.2	120	0	<1
			11-20	930	7	6.0			0.04	0.04		0.01	13		8.1	130	0	3
			11-27	4,600	7	5.5			0.06	0.03		0.16	13		8.2	130	0	6
			12-4	930	3	6.5			0.12	0.09		0.21	[illegible]		8.0	100	0	1
			12-5	930	9	6.0			0.00	0.01		0.03	11		8.3	100	0	4
			12-12	2,400	5				0.04	0.07		0.12	13		8.0	110	0	3
			1-23-52		3	0.0			0.04	0.03		0.07	14		8.2	100	0	<1
			1-28	430		2.0			0.10	0.00								<1
			2-4	4,600	37	2.0			0.05	0.06	0.15	0.03	13		7.6	80	0	<1
			2-19	2,400		2.0												
			2-21									0.10	11					
			2-27		<7										8.0	100		

(1) Facing Upstream

Table B-1 SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Yakima River at Richland Highway Bridge (cont'd)	CY-339	Mid.	3-12-52		<7	4.0	14.2					0.07	10		8.5	100	5	
			4-14	<3.6		12.0												1
			5-7				10.3								8.5	130	10	
			5-8			15.0							17					2
			5-13	430	17	18.0			0.04	0.01		0.22			8.3	100	0	
			5-26									0.01	10					
			6-3		15							0.08	21					
			6-17	2,400														<1
			7-23		30	24.0	11.6								8.3	140		
			9-8		12				0.18	0.00	0.30	0.08			8.2	140	3	
			10-29		18	11.0	9.0								8.0	150		
			2-3-53		170	6.0			0.24	0.00	0.40	0.16			7.6	46	0	0.9
			2-26			6.0												0.5
			3-24			10.0												1.7
Snake River at Page Wash.	CS-342	Mid.	8-17-51		9	22.0	8.5	2.6	0.08		0.07	0.04		13	8.6	140	10	
			8-31		3	19.0	8.9	1.5	0.00	0.02	0.04	0.02	22	16	8.8	150	15	
			3-19-52		22	6.5	11.5								8.0	120		
			3-2[illegible]-53			9.0	10.0								8.1	90		
Snake River near mouth	CS-325	Mid.	8-17-51		7	23.0	9.5	2.7	0.07		0.00	0.02		14	8.6	140	8	
			8-21		10	19.0	7.5	0.80	0.04		0.09	0.02	18	15	8.5	130	5	
			8-31		4	18.5	9.5	0.20	0.04	0.00	0.05	0.00	18	15		140	12	
			9-10	91	8	19.5	9.4	2.4	0.02	0.00		0.00	54		8.8	150	15	
			9-20		15	18.0			0.07	0.00		0.02	40		8.8	150	14	
			11-13	430	9	7.0			0.00	0.03		0.02			8.2	130	0	2
			12-3	430	43	7.0			0.09	0.01		0.12	33		8.3	110	0	4
			12-10	1,500		2.0			0.09	0.02		0.06	25		7.9	100	0	2
			1-8-52		5	0.0			0.14	0.00		0.06	20		8.2	120	0	
			1-21	230	33	2.0			0.04	0.02		0.05			8.2	120	0	
			1-23		46	1.0	13.8								8.4	120	2	
			1-28	930		2.0												2
			2-5	4,600		2.0												
			2-6		>150	4.0	13.1								8.0	92		
			2-12	430		3.0												
			2-21									0.10						
			3-5		10	4.0	13.0								8.4	120	2	
			3-12									0.05						
			4-15	460		10.0												1
			4-30		10	10.5												
			5-6	930	33	16.0			0.12	0.01		0.01			7.8	45	0	<1
			5-13	230	51				0.18	0.00		0.06			8.0	33	0	<1
			5-27										7					
			6-3		15								12					
			6-25		24	17.0	10.5								8.3	55		
			7-7		11				0.05	0.00		0.02	20		8.1	58	0	
			7-23		15	22.0	8.9								8.3	80		
			8-5		12	24.0	9.2								8.3	78		
			10-8		30	17.0	8.9								8.6	140	12	
			11-4		18	9.0	9.7								8.5	150	14	
			2-3-53		60	6.0			0.96	0.00	0.30	0.16	23		8.0	80	0	1.1
			3-24			10.0												<0.7
Walla Walla River at U. S. Highway 410 Bridge	CWw-326	Mid.	8-29-51		9	17.0	8.4	5.9	0.28	0.02	0.01	0.16	54	26		280	30	
			12-5	>11,000	120	6.0			0.03	0.02		0.14	15		8.0	65	0	<1
			3-19-52		26	8.0	11.3								8.1	70		
			4-30		75	12.0												
			6-25		24	19.0	9.7								8.2	130		
			7-23		22	23.0	8.1								8.3	200		
			8-13		50	24.0	8.8								8.4	220	10	
			10-29		20	8.5	9.5								8.2	170	4	
			11-17		20	5.5	11.3								8.2	150		
Walla Walla River at U. S. Highway 395 Bridge	CWw-318	Mid.	8-15-51		16	20.5	7.4	5.2	0.18		0.05	0.14	61	2[illegible]		250		
			8-22		16	19.0	6.1	5.3	0.01	0.03	0.02	0.08	21	5	8.0	220	13	
			8-29		12	16.5	7.9	4.1	0.03	0.02	0.02	0.18	40	27		270	19	
			9-18	1,500	16		7.6	0.80	0.03	0.00		0.00	20			240	0	2
			9-25	430	13	16.5	8.1	1.2	0.02	0.02		0.04			8.4	310	19	1

(1) Facing Upstream

Table B-1 SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Coliforms MPN per 100 ml.	Turb. ppm	Temp °C	D.O. ppm	B.O.D. 5-day ppm	NH_3 ppm	NO_2 ppm	NO_3 ppm	PO_4 ppm	SO_4 ppm	Cl^- ppm	pH	Alkalinity ppm M.O.	Alkalinity ppm Phen.	Activity Density in 10^{-8} µc/ml Gross Beta
Walla Walla River	CWw-	Mid.	11-13-51	4,600	20	6.5			0.00	0.02		0.06			8.1	110	0	2
at U. S. Highway	318		11-20	2,400	16	8.5			0.06	0.07		0.20	18		7.9	90	0	
395 Bridge (cont'd)			11-28			6.0			0.03	0.06		0.15	15		8.4	96	0	
			12-5	11,000	37	5.5			0.02	0.03		0.06	15		8.1	65	0	2
			12-11	4,600	25	2.0			0.06	0.01		0.14	5		7.9	74	0	<1
			1-9-52		43	0.0			0.02	0.00		0.05	4		7.9	82	0	
			1-14		>150	0.0									7.9	86	0	
			1-21												8.2			
			2-12	4,600		2.0												
			4-15	>2,400		10.0												<1
			5-5	2,400														<1
			5-12	1,400	29	11.0			0.03						8.0	50	0	2

(1) Facing Upstream

Table B-2 RESULTS OF MINERAL ANALYSES ON RIVER WATER SAMPLES

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Na	Ca	Mg	Fe	Mn	Zn	Cu	Total Solids	Specific Cond. - µmhos per cm.
				Concentration - Parts per million								
Columbia River below Priest Rapids	C-390	Comp.	5-21-52		16	2.6		0.04		0.008		
			7-30		20	5.7	0.29	0.01	0.00	0.020	40	
Columbia River above Hanford Works	C-385	Comp.	4-17-52		21	8.2	0.08	0.06		0.014		
			5-8		19	7.5	0.07		0.00	0.006		
			9-23		19	6.0	0.08	0.02		0.004	110	120
			12-1		21	3.0	0.14	0.02		0.003	150	120
			1-2-53		21	3.6	0.04	0.01		0.011	86	140
			2-2		20	3.8	0.12	0.01		0.020	92	120
			3-25	2.5	20	6.0	0.07	0.01		0.004	110	
Columbia River at the Hanford Ferry Crossing	C-362	Comp.	2-20-52									
			+2-27		23	5.2	0.05	0.02	0.02	0.012		
			3-13									
			+3-14		22	4.7	0.16	0.03	0.02	0.050		
Columbia River at Richland, Wash.	C-339	Comp.	2-21-52									
			+2-28		24	5.2	0.09	0.01	0.01	0.006		
			4-14									
			+4-18		21	8.6	0.03	0.06	0.02	0.042		
			5-7		21	7.9	0.08	0.08	0.04	0.006		
			5-22		17	2.5		0.06		0.007		
			6-19		17	4.8		0.01	0.02	0.020	68	
			11-19		20	3.3	0.13	0.02		0.004	78	150
			1-8-53		25	4.5	0.05	0.00		0.012	82	170
Columbia River above Kennewick, Wash.	C-330	Comp.	2-19-52									
			+3-3		19	6.0	0.02	0.01	0.02	0.005		
			4-14									
			+4-29		20	7.7	0.04	0.04	0.04	0.016		
			5-7		20	8.2	0.08	0.09	0.08	0.010		
			5-19		16	2.5		0.05		0.016		
			6-19		17	4.5		0.02	0.01	0.040	82	
			7-8		18	4.4	0.14	0.01	0.01	0.002	65	
			7-29		18	6.6	0.36	0.02	0.01	0.002	40	
			9-17		20	7.0	0.26	0.03		0.005	110	150
			11-26		22	3.5	0.07	0.02		0.001	110	120
Columbia River below Pasco, Wash.	C-326	Comp.	2-19-52									
			+3-18		21	5.3		0.03	0.01	0.024		
			6-30		16	4.2	0.18	0.09	0.08	0.002	98	
Columbia River above Walla Walla River	C-316	Comp.	2-20-52									
			+3-18			6.7	0.13	0.03	0.02	0.052		
			4-16		20	7.5	0.13	0.11	0.01	0.024		
			6-30		16	5.3	0.81	0.07	0.08	0.002	120	
			7-31		20	5.2	0.30	0.02	0.00	0.002	68	
			9-24		21	6.0	0.30	0.03		0.006	140	170
Columbia River at Juniper Canyon	C-306	Comp.	2-20-52									
			+3-19		24	5.9	0.06	0.01		0.050		
Columbia River at Paterson, Wash.	C-278	Comp.	4- 8-52									
			+4-18		18	7.5	0.17	0.12	0.04	0.024		
			5-5		16		0.17		0.00	0.016		
			5-20		15	2.4		0.08		0.010		
			7-7		18	4.2	0.33	0.02	0.02	0.002	96	
			9-30		18	8.8	0.19	0.02		0.004	130	190
			11-13		24	5.0	0.16	0.01		0.008	91	190
			12-31		26	5.7	0.08	0.01		0.005	160	190

(1) Facing Upstream

Table B-2 RESULTS OF MINERAL ANALYSES ON RIVER WATER SAMPLES (continued)

Sampling Range	Mileage Index No.	Dist. From Left Shore(1)	Date	Na	Ca	Mg	Fe	Mn	Zn	Cu	Total Solids	Specific Cond. - µmhos per cm.
				Concentration - Parts per million								
Yakima River at Richland Highway Bridge	CY-339	Comp.	2-21-52									
			+3-3		21	7.7	0.08	0.03	0.05	0.012		
			3-12									
			+3-14		33	7.5	0.11	0.03	0.00	0.024		
			4-11		15	4.6	0.12	0.10	0.13	0.480		
			5-8		27		0.03		0.00	0.005		
			5-26		17	4.0		0.08		0.016		
			6-3		17	4.0	1.10	0.04	0.05	0.010	170	
			9-8		31	12	0.46	0.06		0.002	280	310
			2- 3-53		10	4.3	0.93	0.03		0.008	540	110
Snake River near the mouth	CS-325	Comp.	2-21-52									
			+3-4		29	9.3	0.20	0.03	0.03	0.014		
			3-12									
			+3-14		31	11	0.66	0.02	0.00	0.074		
			4-15		16	7.5	0.16	0.17	0.02	0.350		
			5-27			1.0	0.55	0.04		0.015		
			6-3		9.5	1.2	0.68	0.03	0.05	0.006	130	
			7-7		19	4.6	0.45	0.03	0.02	0.020	66	
			2- 3-53		18	6.0	0.32	0.01		0.003	340	170
Walla Walla River at U.S. Highway 395 Bridge	CWw-318	Comp.	4-15-52		16	7.5	0.35	0.59	0.04	0.044		

(1) Facing Upstream

Table B-3 PLANKTON ORGANISMS, COLUMBIA RIVER AND TRIBUTARIES

SAMPLING DATA				PLANKTON WEIGHT		PLANKTON COUNT - AVERAGE NUMBER OF ORGANISMS																																							
						PHYTOPLANKTON - PER MILLILITER																																				ZOOPLANKTON - PER LITER				
						BACILLARIOPHYCEAE (DIATOMS)													CHLOROPHYCEAE (GREEN ALGAE)								MYXOPHYCEAE											GRUSTACEA				
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample	Wet Weight Mgms/Liter	Organic Matter Mgms/Liter	Asterionella sp	Ceratoneis sp	Cocconeis sp	Cyclotella sp	Cymbella sp	Diatoma sp	Fragilaria sp	Gomphonema sp	Melosira sp	Navicula sp	Stephanodiscus sp	Synedra sp	Tabellaria sp	Other	TOTAL	Ankistrodesmus sp	Coelastrum sp	Pandorina sp	Pediastrum sp	Scenedesmus sp	Stigeoclonium sp	Ulothrix sp	Other	TOTAL	Oscillatoria sp	Other	TOTAL	PIGM. FLAGELLATES TOTAL	PHYTOPLANKTON TOTAL	FIL. BACTERIA AND FUNGI - PER LITER	PROTOZOA TOTAL	Cladocera	Copepoda	TOTAL	ROTIFERA TOTAL	MISCELLANEOUS	ZOOPLANKTON TOTAL
Columbia River at Priest Rapids	C-400	West shore	1-15-52	1.46	0.28	5	15		5	5		10	5	25	99		5		20	194																									
			2-11-52	1.87	0.38	8	17			4	2	6	30	10	75		19	4	26	201	40								40					234										
		Comp.	3-10-52	3.60	0.45		83	3		19	45	2	76	9	42	1	19	3	37	345	50							1	51				19	271	5	20		5	5		5	30
			4-28-52	11.71	1.25	17			1	2	3		2	7	7		40		3	82	10						1	1	12				7	364	5	35				15	15	65
			5-12-52	13.24	1.08	585	5		14	5	2	10	5	44	7		140	24	12	853	10							1	11				1	94	10	10						10
			6-2-52	6.13	0.61	229			187	7		66	2	30	2	2	113	81	62	781	10				5		2		17				17	886						20	20	40
			7-28-52	2.79	0.59	16		1	7	12		57	1	18	2		1	5	2	122	13				4			5	22	2		2	25	823		10		5	5	30		45
			8-11-52	2.61	0.79	20	1		25	23		65	1	36	10		11	1	9	202	62				3	1	1	1	68	280		280		146	10		20	20	55	5	80
			9-15-52	3.84	0.75	1		1	10	2		2		65	6	6	5		6	104	4				6				10		1	1		115	50					15	5	20
			10-13-52	4.98	0.55	2		1	6	3		1		65	13		1		7	99	5			1	15			2	23	1	9	10		132		20					10	30
			11-10-52	2.16	0.55			1	9	1	2	4	1	40	5		1		2	66	3				2			3	8		3	3		77		10				15	10	35
		West shore	12-10-52	1.53	0.37	2		1	5	6				18	20		1		1	54	15							2	17		1	1		72		5				5	5	15
Average				4.66	0.44	74	10	0	23	7	5	19	10	31	24	0	30	10	16	259	20			0	3	0	0	1	25	24	1	25	6	314	8	11		4	4	16	7	38
Maximum				13.24	1.25	585	83	3	187	23	45	66	76	65	99	6	140	81	62	853	62			1	15	1	2	5	68	280	9	280	25	886	50	35		20	20	55	20	85
Minimum				1.46	0.28	0	0	0	0	1	0	0	0	7	2	0	1	0	1	54	3			0	0	0	0	0	8	0	0	0	0	72	0	0		0	0	0	0	0
Columbia River above Hanford Works	C-385	West shore	1-15-52	15.99	1.18			5		15				69	138		5		15	247	29								29				5	281		10						10	20
			2-11-52	2.69	0.39	7	38	5	4	6	12	3	62	12	77		16	4	4	250	16								16				3	269	5	120				10	3	135
		Comp.	3-10-52	2.79	0.34	2	60	1	6	15	25		69	14	25	1	19	2	36	275	9						3	3	15					299	15	35				10	5	50
			4-28-52	6.28	0.66	27	6	1	3	12	5	7	12	24	17		31	3	11	159	12							8	20	1		1	2	182		30				10	20	60
			5-12-52	13.12	1.05	644	1	2	16	8	8	5	8	46	3		162	33	8	942	5							1	6				27	975						10	10	20
			8-11-52	3.44	0.94	15		1	29	35		93	2	43	14		16		14	262	97				3			1	101	357		357	1	721	20	40		5	5	30		75
			11-10-52	3.08	0.44		1	3	13	2	1	6	6	42	13		2		3	92	5							1	6		6	6		104	15	40		5	5	15	35	95
			12-15-52	1.93	0.43			1	3	7		1	5	23	20		1		1	62	3							1	4	1		1		67		5				5		10
Average				6.41	0.68	87	13	2	9	13	6	14	20	34	38	0	31	5	12	286	22				0		0	2	25	45	0	46	5	361	7	35		1	1	11	11	58
Maximum				15.99	1.18	644	60	5	29	35	25	93	69	69	138	1	162	33	36	942	97				3		3	8	101	357	6	357	27	975	20	120		5	5	30	35	135
Minimum				1.93	0.34	0	0	1	0	2	0	0	0	0	3	0	1	0	1	62	3				0		0	0	4	0	0	0	0	67	0	0		0	0	0	0	10
Columbia River above Coyote Rapids	C-383	West shore	1-15-52	1.66	0.72	3	1	1	4	2	3		4	17	31		3			69	20								20					89									
			2-11-52	3.06	0.35	10	30	2	2	3	8	5	41	10	55		15	2	5	188	32						1		33					221	5	20				5	5	30
		Comp.	3-10-52	4.07	0.48	5	67	1	7	16	34	2	89	12	59		18	2	27	335	15						1		16				2	353	5	10		5	5	20	5	40
			4-28-52	13.09	1.44	14	3		1	8	1	1	3	10	10		30	2	9	92	3						1		4				2	98						15	45	60
			5-12-52	11.71	1.01	568	6	2	11	8	3	14	7	23	6		130	33	11	822	11							1	12				5	839	10						10	10
			6-2-52	6.90	0.64	330			153		5	76		37	2	2	98	59	47	809								2	2				22	833								
			7-28-52	2.85	0.63	18				12		66	1	21	5		6	3	3	135	18				1			1	20				8	163	10	70		5	5	65		140
			8-11-52	3.47	0.73	16			21	23		77	2	39	7		6	1	6	198	63							1	44	237		237		499	60	55		5	5	25		85
			9-11-52	3.77	0.56			1	28	8		4	3	65	10	3	9		5	136	10				7	1	1	1	20	1		1		157	90	20				5	15	40
			10-13-52	2.60	0.52	3		2	16	3	1	2	1	70	25		4		4	131	3				12			2	17	2	7	9		157	20	45				15	5	65
			11-10-52	2.77	0.47	1		2	13	2	2	8	5	41	16				5	95	2				1			1	4		4	4		103	15	40				20	60	120
			12-15-52	1.13	0.29	3		2	5	4		4	2	16	18				5	59	11				1			1	13					72							5	5
Average				4.76	0.65	81	9	1	22	7	5	22	13	30	20	0	27	9	11	257	16				2	0	0	1	19	20	1	21	33	299	18	23		1	1	14	13	41
Maximum				13.09	1.44	568	67	2	153	23	34	77	85	70	59	3	130	59	47	822	63				12	1	1	2	64	237	7	237	22	839	90	70		5	5	65	60	140
Minimum				1.13	0.29	0	0	0	0	0	0	0	0	10	2	0	0	0	0	59	0				0	0	0	0	2	0	0	0	0	72	0	0		0	0	0	0	0

Table B-3 PLANKTON ORGANISMS, COLUMBIA RIVER AND TRIBUTARIES

SAMPLING DATA				PLANKTON WEIGHT		PLANKTON COUNT - AVERAGE NUMBER OF ORGANISMS																																						
						PHYTOPLANKTON - PER MILLILITER																																		ZOOPLANKTON - PER LITER						
						BACILLARIOPHYCEAE (DIATOMS)														CHLOROPHYCEAE (GREEN ALGAE)								MYXOPHYCEAE											CR. STAGEA					
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample	Wet Weight Mgms/Liter	Organic Matter Mgms/Liter	Asterionella sp	Ceratoneis sp	Cocconeis sp	Cyclotella sp	Cymbella sp	Diatoma sp	Fragilaria sp	Gomphonema sp	Melosira sp	Navicula sp	Stephanodiscus sp	Synedra sp	Tabellaria sp	Other	TOTAL	Ankistrodesmus sp	Coelastrum sp	Pandorina sp	Pediastrum sp	Scenedesmus sp	Stigeoclonium sp	Ulothrix sp	Other	TOTAL	Oscillatoria sp	Other	TOTAL	FLAGELLATES TOTAL	PHYTOPLANKTON TOTAL	FIL. BACTERIA AND FUNGI - PER LITER	PROTOZOA TOTAL	Cladocera	Copepods	TOTAL	ROTIFERA TOTAL	MISCELLANEOUS	ZOOPLANKTON TOTAL
Columbia River at Hanford Ferry Crossing	C-362	Mid-stream	12-11-51	2.98	0.64	9		34	34	5	10	69	29	153	310		34		10	697	39								5	44		20	20		761	20	10				10	20	40
			1-22-52	1.89	0.32	4	9	3	20	6	6	1	12	15	49		5			130	20					1			21					151		20		10	10	5	15	50
			2-5-52	2.70	0.43	14	23	5	8	9	19	8	29	24	77		12	5	7	240	37							3	40					280	10	5				5		10
		Comp.	3-3-52	3.71	0.45	5	70	6	6	13	28	1	77	16	57		12	2	22	315	10				1				11				6	332		75		5	5	10	5	95
			4-7-52	7.52	0.92	10	16	5	4	22	16	1	32	20	19		59	3	16	223	14						1	18	33				28	284	10	5				10	15	30
			5-6-52	23.76	2.37	461	10	1	3	33	3	26	29	44	31		96	14	31	782	19	1					1		21				45	848		10	10		10	10	50	80
			6-16-52	6.15	0.88	248		2	84	5		224	5	20	30		94	69	47	828	15						5	10	30				5	863		15		5	5	40	5	65
			7-22-52	2.44	0.58	22	5			15		204	2	20	17		12	5	25	327	44		2		2			39	87		7	7	49	470		40		5	5	45		90
			8-4-52	3.65	0.73	36	2	1	13	30		48	2	40	8		14	5	14	213	68	1			1			0	79		65	65		357	20	40		5	5	10		55
			9-9-52	3.72	1.25			1	7	6			1	22	5		6		2	50	3				1				4				1	55	15	10				5		15
			10-7-52	3.28	0.47	1		3	23	9	1	9	6	62	20		11		11	176	8				15			2	25	1	2	3		204		25		5	5	15	40	85
			11-3-52	4.00	0.94	1		3	11	7	1	13	7	49	24		2		3	121	10				2			8	20		1	1		142	5	70				10	10	90
			12-8-52	1.52	0.45	4		2	7	8		3	3	17	20	1			3	62	21				3				24					92	5	10				5	10	25
Average				5.17	0.80	63	10	5	17	13	6	47	18	40	51	0	27	8	15	320	23	0	0		2	0	0	7	34	0	7	8	10	372	7	26	1	3	3	14	13	54
Maximum				23.76	2.37	461	70	34	84	33	28	224	77	153	310	1	96	69	47	828	68	1	2		15	1	5	39	87	1	65	65	49	863	20	75	10	10	10	45	50	95
Minimum				1.52	0.32	0	0	0	0	5	0	0	1	15	5	0	0	0	0	50	3	0	0		0	0	0	0	4	0	0	0	0	55	0	5	0	0	0	5	0	10
Columbia River at Richland, Wash.	C-339	Mid-stream	10-1-51	3.36	0.70	11		3	9	7	7	1	8	40	71		8			165	3								3					168								
		West shore	1-22-52	2.16	0.36	3	3	8	28	6	15	2	13	20	132		4			234	23				1	1	1	2	28				1	243	5	25		25	25	5	5	60
			2-5-52	2.60	0.53	11	17	2	8	11	53	2	48	14	214		24	9	7	420	12				1			1	14	1		1	1	436	5	5	5		5	5		15
		Comp.	3-3-52	3.68	0.39	5	105	3	11	30	55	2	107	18	115		25	5	33	513	9						3		12		1	1	2	528	5	75		5	5	10	20	110
			4-7-52	8.57	0.97	10	24	3	2	26	32	1	62	28	23	1	55	6	23	295	18						3	28	49				23	367	15							
			5-5-52	19.86	1.60	209	7	6	5	25	1	43	44	86	23		35	7	27	516	1						2	1	6	2		2	38	562	30	30				10	10	50
			6-17-52	4.77	0.65	354	5		123	5		256	5	20	20	2	123	98	19	1050	34				7		2	42	85					1135		35	5	5	10	85	75	205
			7-15-52	2.55	0.73	74			12	12		273	2	49	7		15	47	15	507	49		288		7			103	447				49	1003		60		10	10	5		75
			8-4-52	6.49	0.68	37	3	2	19	34		48	5	52	8		16		13	257	54				5			2	61	58		58	2	378	55	30				15		45
			9-9-52	8.23	3.38		1	1	23	18		6	4	126	3		14		1	197	1				1				2					199	20							
			10-6-52	3.96	0.57	3		3	25	7	1	6	3	77	17		11		4	177	17				16			1	34					211	10	95				10	80	185
			11-4-52	2.43	0.56	1		3	13	3		9	8	42	23		2		5	109	11				5			10	26		1	1		136		15				5	50	70
			12-10-52	2.70	0.50	1	1	5	8	11	1	17	8	28	63				8	151	14				1			1	16	1		1		168		15				5	25	45
Average				5.43	0.89	55	13	3	22	15	13	51	24	46	55	0	29	13	13	357	18		22		3	0	1	15	59	5	0	5	9	427	11	30	1	3	4	12	21	66
Maximum				19.06	3.38	354	105	8	123	34	55	273	107	126	214	2	123	98	39	1050	54		288		16	1	3	103	447	58	1	58	49	1135	55	95	5	25	25	85	80	205
Minimum				2.16	0.36	0	0	0	2	3	0	1	2	16	2	0	0	0	0	109	1		0		0	0	0	0	2	0	0	0	0	136	0	0	0	0	0	0	0	0
Columbia River above Kennewick, Wash.	C-330	Mid-stream	10-10-51	3.80	0.83			5	20	3	17		9	20	153		6		1	234	9								9	1		1		244		10					10	20
		West shore	1-21-52	2.87	0.45	1	6	1	11		5		5	3	116		5			153	20							1	21					174		10					10	20
			2-4-52	18.91	1.91		10	10	20	20	98	20	29	39	720		49			1015	39							20	59				39	1113								
		Comp.	3-3-52	2.24	0.39	4	104	1	18	26	31		82	18	119		22	2	14	441	14						3	1	18					459	5	75				10	18	98
			4-8-52	7.98	1.00	4	24	6	2	28	43	5	61	22	49		31	3	16	294	10				1			31	42				39	375						10	30	40
			5-5-52	27.58	2.29	266	16	7	5	37	6	34	29	61	27		53	15	31	587							1		1				36	624		20				10	50	80
			6-9-52	4.47	0.50	325			101	12	7	101		29	42	2	52	69	62	778	22				2			12	36				10	824						20	20	40
			8-5-52	2.72	0.37	37		1	27	31		36	2	46	13		41	1	9	244	35				7	1		2	45	27		27	1	317	25	30				25	10	65
			9-8-52	6.89	2.93				6	1	1	5	1	92	5		44		1	162	1			1	2				4	1		1		167	10					25	5	30
Average				8.36	1.20	71	18	3	23	17	23	42	26	36	138	0	36	10	13	436	17			0	1	0	0	7	26	3		3	14	477	4	16				11	14	43
Maximum				27.58	2.93	325	104	10	101	37	98	101	82	92	720	2	53	69	62	1015	39			1	7	1	3	31	59	27		27	39	1113	25	75				25	50	95
Minimum				2.24	0.39	0	0	0	2	0	0	0	0	3	5	0	5	0	0	153	0			0	0	0	0	0	1	0		0	0	167	0	0				0	0	0

Table B-3 PLANKTON ORGANISMS, COLUMBIA RIVER AND TRIBUTARIES

SAMPLING DATA				PLANKTON WEIGHT		PLANKTON COUNT - AVERAGE NUMBER OF ORGANISMS																																											
						PHYTOPLANKTON - PER MILLILITER																																											
						BACILLARIOPHYCEAE (DIATOMS)																		CHLOROPHYCEAE (GREEN ALGAE)										MYXOPHYCEAE									ZOOPLANKTON - PER LITER						
																																													GRUSTACEA						
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample	Wet Weight Mgms./Liter	Organic Matter Mgms./Liter	Asterionella sp	Ceratoneis sp	Cocconeis sp	Cyclotella sp	Cymbella sp	Diatoma sp	Fragilaria sp	Gomphonema sp	Melosira sp	Navicula sp	Stephanodiscus sp	Synedra sp	Tabellaria sp	Other	TOTAL	Ankistrodesmus sp	Coelastrum sp	Pandorina sp	Pediastrum sp	Scenedesmus sp	Stigeoclonium sp	Ulothrix sp	Other	TOTAL	Oscillatoria sp	Other	TOTAL	PIGM FLAGELLATES TOTAL	PHYTOPLANKTON TOTAL	FIL BACTERIA AND FUNGI - PER LITER	PROTOZOA TOTAL	Cladocera	Copepoda	TOTAL	ROTIFERA TOTAL	MISCELLANEOUS	ZOOPLANKTON TOTAL
Columbia River below Pasco, Wash.	C-326	Mid-stream	11-8-51	4.67	1.09				79		79			20	126					304	39						20	10	69					375		60					20	40	120
		W.Shore	1-23-52	2.12	0.41	5				15	79	10	15	25	271		30		50	500	44							5	49					549	20	50		30	30	30	10	120
			2-6-52	5.99	1.15	8	12	2	7	3	24	9	5	11	210		7		11	305	1							5	6				13	324		30		20	20		10	60
		Comp.	3-3-52	3.57	0.52	1	74	7	7	13	35	1	52	13	139		22	4	15	383	6								6					389		10						10	10
			4-8-52	6.99	0.92	11	16	1	4	21	15	2	31	6	38		62	3	15	225	26				1			22	49				17	291				5	5	15	5	25
			5-5-52	20.87	1.72	272	11	2	3	32	9	43	28	70	18		72	19	27	604	3							1	4	1		1	41	652	10	10					30	80	120
			6-9-52	8.82	1.16	251			84	5	2	79	2	30	27		155	27	10	672	10				2			2	14				2	688		10		20	20	20	15	60
			7-15-52	4.79	1.12	91			192	17		209	2	25	32		17	27	20	632	39		248		7			111	405				86	1123		55	5		9	5		75
			8-5-52	3.50	0.98	36	2		62	29		34	2	37	16		55	1	16	284	35				5			1	41	2		2	3	330	10	25					45	5	75
			9-8-52	4.98	0.78		1	1	5	11		9	2	102	5		28		7	171	1				1	1			3				1	175	15	10					15		25
			10-8-52	4.37	0.45	2		3	41	7	1	11	7	71	39		21		12	215	17				27			7	51	1	6	7		273	10	50					30	35	115
			11-6-52	2.97	0.44	1		2	11	2	1	11	4	35	18		3		3	91	3				3			6	12					103	25	15					10	30	55
			12-17-52	2.29	0.45	2		3	12	9	4	3	5	20	61		2		2	123	14			1	1			1	17					140								15	15
Average				6.14	0.87	52	9	2	39	13	19	32	12	36	77	0	36	6	16	347	18		19	0	4	0	1		56	0	0	0	12	416	7	25	0	0	6	18	9	60
Maximum				20.87	1.72	272	74	7	192	32	79	209	52	102	271	0	155	27	50	672	44		248	1	27	1	20		405	2	6	7	86	1123	25	60	5	30	30	45	80	120
Minimum				2.12	0.41	0	0	0	0	0	0	0	0	6	5	0	0	0	0	91	1		0	0	0	0	0		3	0	0	0	0	103	0	0	0	0	0	0	0	0	0
Columbia River above Walla Walla River	C-316	E.Shore	11-8-51	8.20	1.28		10	10	3250	30	20		20	20	230	10	39		69	3714					10			20	30				79	3823		80					40	120
		W.Shore	1-23-52	8.85	1.23	3	6	15	33	10	22	1	17	14	152		9		2	284	10							1	11				12	307		80					15	95
		W.Shore	2-6-52	18.73	1.71	7	6	7	16	7	27	2	19	10	182		18		3	304	3						1		4				5	313		40					15	55
		Comp.	3-5-52	9.02	0.90	3	42	9	383	18	21		79	20	108		23		32	738	10						1	9	20				26	784	20	140				10	30	180
			4-23-52	69.30	5.08	16	7		9	18	20	5	16	16	45		29		16	199	2	2						5	9				16	224							20	20
			5-7-52	56.25	4.13	226	9	5	2	23	9	23	5	61	34		16	2	18	433								2	2		2	2	25	462				20	20		40	60
			8-13-52	14.78	2.45	9			93	36	5	63		59	18		77		11	374	9			5	36				48		445	445	2	869		60		40	40	40		140
			11-17-52	4.01	0.80	13		6	67	16	22	4	7	23	31	3	3		5	200	3				3		1	1	8		2	2		210	20						5	20	25
Average				23.64	2.21	35	10	7	481	19	18	12	20	28	100	3	27	0	20	781	5	0		0	6		0	5	17	0	54	56	21	874	5	50		7	7	7	22	87
Maximum				69.30	5.08	226	42	15	3250	36	27	63	79	61	236	10	77	2	69	3714	10	2		5	36		1	20	48	0	445	445	79	3823	20	140		40	40	40	40	180
Minimum				4.01	0.80	0	0	0	2	7	5	0	0	10	18	0	3	0	2	199	0	0		0	0		0	0	2	0	0	0	0	210	0	0		0	0	0	0	0	0
Columbia River at Juniper Canyon	C-306	E.Shore	11-8-51	9.29	1.73	10			3390	30	59		30	59	454		30		20	2062								10	10				49	2141		100					40	140
			1-10-52	5.81	1.16	2	1	6	385	4	5		3	1	73		6		5	991	7						1		8					999		20					10	30
			2-20-52	21.89	1.82		15	13	19	10	19	1	17	11	129		16		2	252	6								6					258		160					50	210
		Comp.	3-5-52	13.21	1.38		58	21	549	15	23		50	18	158		11		38	938	8							8	16				63	1017		30				40	10	140
			4-23-52	97.44	6.22	2	7	2	30	11	23	2	5	18	62		18		9	176					2			2	4				7	187							40	40
			5-7-52	44.59	3.35	489	16	2	9	32	11	43	32	81	63		66	9	43	796							2	5	7	1		1	38	842				20	20			20
			8-18-52	8.29	0.87	201			38	2	2	85	1	36	4	4	12	60	7	512	2		1		3			4	10	1		1	41	652	5			15	15	30		105
			7-9-52	5.19	1.10	111			1132	10	2	226	2	32	32		25	36	7	1611	27	12	52		37			91	219	2		2	54	1886		10		5	5	15		30
			8-13-52	14.43	2.30	20	2	3	79	45		70		61	27		140		20	469	27			2	36			4	69	398		398	2	898	60	80				40		120
			10-20-52	6.82	1.27	37		11	740	9	7	17	3	70	37	191	11		10	1143	5				10			10	33	1	5	6	1	1183		40				30	40	110
			11-17-52	4.18	0.74	25		10	713	27	15	5	20	32	38	49	10		30	1038	7				12			7	26				10	1068		10	5	5			5	20
			12-17-52	2.88	0.53	25		22	625	27	71	2	12	30	157	10	7		17	1008	12				2			10	24	2		2	7	1038		25				5	40	70
Average				18.67	1.87	70	8	8	532	18	20	37	14	37	104	21	28	8	17	917	8	1	4	0	9		0	13	36	34	0	34	19	1006	4	44		4	4	10	19	84
Maximum				97.44	6.22	489	58	22	3390	45	71	226	50	81	454	191	140	60	43	2062	27	12	52	2	37		2	91	219	398	5	398	63	2141	40	160		20	20	90	50	140
Minimum				2.88	0.53	0	0	0	9	2	0	0	0	1	5	0	5	0	2	176	0	0	0	0	0		0	0	6	0	0	0	0	187	0	0		0	0	0	0	20

Table B-3 PLANKTON ORGANISMS, COLUMBIA RIVER AND TRIBUTARIES

SAMPLING DATA				PLANKTON WEIGHT		PLANKTON COUNT - AVERAGE NUMBER OF ORGANISMS																																						
						PHYTOPLANKTON - PER MILLILITER																																		ZOOPLANKTON PER LITER				
						BACILLARIOPHYCEAE (DIATOMS)														CHLOROPHYCEAE (GREEN ALGAE)								MYXOPHYCEAE										CRUSTACEA					
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample	Wet Weight Mgms/Liter	Organic Matter Mgms/Liter	Asterionella sp	Ceratoneis sp	Cocconeis sp	Cyclotella sp	Cymbella sp	Diatoma sp	Fragilaria sp	Gomphonema sp	Melosira sp	Navicula sp	Stephanodiscus sp	Synedra sp	Tabellaria sp	Other	TOTAL	Ankistrodesmus sp	Coelastrum sp	Pandorina sp	Pediastrum sp	Scenedesmus sp	Stigeoclonium sp	Ulothrix sp	Other	TOTAL	Oscillatoria sp	Other	TOTAL	PIGM FLAGELLATES TOTAL	PHYTOPLANKTON TOTAL	FIL BACTERIA AND FUNGI - PER LITER	PROTOZOA TOTAL	Cladocera	Copepoda	TOTAL	ROTIFERA TOTAL	MISCELLANEOUS	ZOOPLANKTON TOTAL
Columbia River above McNary Dam	C-297	W.Shore	1-10-52	5.48	0.79		5		1230	5		168	39	100	440		158		59	2204	44								44					2248	30	129						20	140
			2-13-52	24.08	2.09	5	26	8	13	2	30	5	45	9	115	10	20		2	290	5							1	6				3	299		15					25	40
		Comp	3-12-52	73.57	6.11		54	5	14	9	63	4	16	14	185		9		14	407													18	425						80	80	160
			4-23-52	91.49	6.50	2			7		14			2	20				7	52								2	2	4				2	58						20		20
			5-16-52	30.91	1.98	475	1	3	27	8	5	12	5	35	21		64	18	3	677	2						3		5				18	700						85		90
			6-18-52	11.74	1.54	449		5	744			138	10	212	30		138	59	54	1839	15	5		10	15			20	65				36	1938		5				85		90
			7-9-52	4.64	0.97	93	2		1146	5		89	2	62	18	7	7	20	10	1453	2	5	27	10	20		2	59	125				42	1620		30				20		50
		W.Shore	8-6-52	7.40	0.93	58	2	6	148	23		88	14	54	32		87		16	529	18			5	21	1		9	54	19		19	18	611		10				20	10	40
		Comp	9-10-52	9.05	1.55		1	1	556	12	2	33	2	47	25	198	67		8	1152	5			6	41			16	68		2	2	6	1226	10	10				30	20	60
			10-15-52	11.76	2.09	16		5	668	3	3	7	2	76	14	470	12		3	1279	3			2	43			5	53	1		1		1333		5				10		15
			11-5-52	7.83	1.37	84		20	3120	29	10	20	15	89	138	103	15		59	3702	5				39			108	152		5	5	20	3879		10				10	30	50
			12-17-52	3.72	0.68	49		5	836	5	74	12	22	49	157	20	47		22	1296	12				5			10	27					1323		20				10	20	50
Average				23.47	2.22	102	7	5	709	8	17	48	16	62	99	84	52	8	21	1240	9	1	2	3	15	0	0	19	50	2	1	2	42	1305	3	19				24	17	61
Maximum				91.49	6.50	475	54	20	3120	29	74	168	45	212	440	470	158	59	59	3702	44	5	27	10	41	1	3	108	152	19	5	19	13	3879	30	120				85	90	160
Minimum				3.72	0.68	0	0	0	7	0	0	0	0	2	10	8	0	0	2	52	0	0	0	0	0	0	0	0	0	0	0	0	0	58	0	0				0	0	0
Columbia River at Paterson, Wash	C-278	Mid-stream	1-10-52	8.42	1.20	2		12	1053	12	15		17	25	229	5	20		22	1412	22				2			5	29				20	1461	5	40		5	5		25	70
			2-13-52	25.[illegible]	2.89		30		30	10	19	10	30		177		30			336														336		40					20	60
		Comp	3-27-52	14.99	1.38	1	18	9	41	6	12	1	23	12	97		14	2	8	244							2		2				22	268		65				5	30	100
			4-23-52	81.61	5.47	2	2	5	23	9	18		7	2	45		11		23	147													18	165								
			5-14-52	33.67	2.20	304		5	19	8	8	16	5	18	18		27	21	2	451	1						2	1	4				17	472								
			6-18-52	12.38	1.57	636			498	15	10	163		182	49	5	74	64	79	1775	5								25				30	1830		25	5		5	140		170
			7-9-52	4.82	1.06	143			1141	10		148		32	20	2	15	39	17	1567	20	15	42	2	22		4	59	162				36	1763		15				10		25
			8-6-52	4.38	0.88	51	1		179	20		74	2	35	13		91		5	471	9	3		11	39	1	1	10	74	25		25	5	575	15	40		5	5	10		55
			9-10-52	8.33	2.02	1	1		612	3	1	42	1	50	24	172	76		10	993	14			5	34			17	70		2	2	5	1070		10				20	10	40
			10-15-52	15.16	2.24	26		2	816	8	6	15		116	19	570	13		10	1601	3			2	55			15	75	3	3	6		1682		20				10	10	40
			11-5-52	7.17	1.36	93		15	6935	15	20	20	25	79	99	345	10		39	5695	5				39			104	168					5863		10				30	30	70
			12-17-52	6.52	0.98	15		7	467	12	81		15	15	118	7	15		22	774	17				2			2	21					795						5	5	10
Average				18.59	1.93	106	4	5	818	11	16	41	10	47	76	92	33	10	19	1289	8	1	3	2	16	0	1	18	51	2	0	3	13	1355	2	20	0	1	1	19	11	53
Maximum				81.61	5.47	636	30	15	6935	20	81	163	30	182	229	570	91	64	79	5695	22	15	42	11	55	1	2	104	162	25	3	25	36	5863	15	65	5	5	5	140	30	170
Minimum				4.38	0.88	0	0	0	19	3	0	0	0	0	13	0	10	0	0	147	0	0	0	0	0	0	0	0	0	0	0	0	0	165	0	0	0	0	0	0	0	0
Yakima River at Richland Highway Bridge	CY-339	S.Shore	1-10-52	2.08	0.59			2	54	27	148		39	2	1225		25			1522														1522		90				35	30	155
			2-27-52	6.52	0.77		2	11	70	36	76	1	26	6	1102		22		21	1369					1				1	1		1	6	1377		235				30	50	315
			3-12-52	3.03	0.84			3	555	49	45		16	1	1032		39		1	1741	1			1	1	1		1	5	1		1	1	1749		265				15	100	380
	CY-343	W.Shore	4-23-52	45.72	4.06	3	11	7	10	7	67	1	10	6	244		37		11	414	1								1				6	421		10					60	70
	CY-339	Mid-stream	5-7-52	5.72	1.11	54		30	676	7	231		32		509		34		20	1795				2	5		7	10	24				76	1895						10	35	45
	CY-343	W.Shore	6-23-52	12.37	2.06			84	3253	15	120		98	10	3030		138		64	3816					23			10	35				656	4507	10	220				20		240
	CY-339	Mid-stream	7-23-52	44.00	5.88			108	9956		30		10	30	286		562		20	10,502			10		20			148	178	20		20	168	10,848		100				100		200
	CY-343	W.Shore	9-9-52	24.04	2.61				9	2				5	22		800			838	2								2				16	856		20				20	40	80
	CY-339	Mid-stream	10-20-52	17.29	1.89			18	16	7	52		7	9	288		32		20	441					7			2	9	16		16		466		180				20	20	220
Average				17.04	2.20	6	1	49	1438	17	86	0	26	7	637	0	188	0	17	2493	0	0	1	0	6	0	1	19	28	4		6	191	2684	1	104				32	37	190
Maximum				45.72	5.88	54	11	108	9956	49	231	1	98	30	1225	0	800	0	64	10,502	2	0	10	2	23	1	7	148	178	20		20	656	10,848	10	265				180	100	380
Minimum				2.08	0.59	0	0	0	9	0	0	0	0	0	22	0	22	0	0	414	0	0	0	0	0	0	0	0	0	0		0	0	621	0	0				0	0	45

Table B-3 PLANKTON ORGANISMS, COLUMBIA RIVER AND TRIBUTARIES

SAMPLING DATA				PLANKTON WEIGHT		PLANKTON COUNT - AVERAGE NUMBER OF ORGANISMS																																							
						PHYTOPLANKTON - PER MILLILITER																																				ZOOPLANKTON - PER LITER					
						BACILLARIOPHYCEAE (DIATOMS)													CHLOROPHYCEAE (GREEN ALGAE)									MYXOPHYCEAE											CRUSTACEA				
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample	Wet Weight Mgms/Liter	Organic Matter Mgms/Liter	Asterionella sp	Ceratoneis sp	Cocconeis sp	Cyclotella sp	Cymbella sp	Diatoma sp	Fragilaria sp	Gomphonema sp	Melosira sp	Navicula sp	Stephanodiscus sp	Synedra sp	Tabellaria sp	Other	TOTAL	Ankistrodesmus sp	Coelastrum sp	Pandorina sp	Pediastrum sp	Scenedesmus sp	Stigeoclonium sp	Ulothrix sp	Other	TOTAL	Oscillatoria sp	Other	TOTAL	PIGM FLAGELLATES TOTAL	PHYTOPLANKTON TOTAL	FIL BACTERIA AND FUNGI - PER LITER	PROTOZOA TOTAL	Cladocera	Copepoda	TOTAL	ROTIFERA TOTAL	MISCELLANEOUS	ZOOPLANKTON TOTAL
Snake River near mouth	CS-325	N.Shore Comp.	1-25-52	13.17	1.64			5	306	20	20		10	5	252		30		20	668								10	10				25	703		210				20	10	240
			3-5-52	17.73	1.93	1	6	19	854	18	7		16	1	158	2	9		16	1107								3	3				121	1231	20	100				10	20	130
			6-26-52	15.80	2.56	414	9		1518		10	49		468	20	10				2494		9						20	29				76	2597		60				105		165
			7-23-52	13.81	2.87	5	5		2642	5	5	35	10	150	212		5		15	3097	54	266		54	424			439	1237				5	4339		15				15		30
			8-5-52	12.38	3.39		5	10	2598	35		97		39	104		197		59	3144	108	242		143	613			533	1539					4683		3710		10	10	80		3800
			10-8-52	33.05	6.24	113	9	27	3376	23	9	136	9	271	68	1135	18		45	5239	45			18	285			81	429		16	16		5686								
			11-4-52	12.87	2.72	197		5	4580	25	20	30	15	89	69	532	10		10	5582					25			74	99				104	5785		70				10	50	130
Average				16.97	3.05	104	4	9	2268	18	10	49	8	147	126	240	30	0	23	3047	29	74		31	178			166	478		2	2	47	3575	3	595		1	1	36	11	642
Maximum				33.05	6.24	414	9	27	4580	35	20	136	16	468	252	1135	197	0	59	5582	108	266		143	513			533	1539		18	16	121	5785	20	3710		10	10	105	50	3800
Minimum				12.38	1.64	0	0	0	306	0	0	0	0	1	20	0	0	0	0	668	0	0		0	0			3	3		0	0	0	703	0	0		0	0	0	0	0
Walla Walla River at Old Highway Crossing	CWw-322	N.Shore	6-25-52	24.58	2.80			16	353	59	5		52	2	459		52		16	1014														1016								
			7-23-52	14.81	6.45		1	2	59	17			5		104		11		6	205					2			2	2													
		Mid-stream	8-13-52	34.16	9.46				8016	39		985		5487	394				236	67,304	591				118			34	36				18	259		55				15	5	75
			10-29-52	16.35	2.16			25	11	23	77				136		2		55	329					2			7565	8274	79	39	118		75,690		45,300				2700		48,000
		N.Shore	11-17-52	11.38	1.46			7	25	32	178			2	118				50	402					2		4	2	8		2	2		339		120				40	100	260
Average				20.26	4.47	0	0	10	2222	34	52	197	11	3098	242	0	13	0	71	13,85	1,110				25		1	1521	1664	16	8	24	3	15,542		9111				559	61	9711
Maximum				34.16	9.46	0	1	25	8016	59	178	985	52	5487	459	0	52	0	236	67,304	591				118		4	7565	8274	79	39	118	18	75,690		45,300				2720	100	48,000
Minimum				11.38	1.46	0	0	0	11	17	0	0	0	0	104	0	0	0	6	205	0				2		0	0	2	0	0	0	0	259		0				6	0	0

Table B-4 BOTTOM FAUNA, COLUMBIA RIVER AND TRIBUTARIES

SAMPLING DATA						ORGANISMS																					
Sampling Range	Mileage Index Number	Location of Sample (1)	Date of Sample	Type and Size of Sample		TURBELLARIA (Flatworms)	NEMATODA (Roundworms)	OLIGOCHAETA (Aquatic Earthworms)	HIRUDINEA (Leeches)	ARACHNOIDAE Hydracarina (Water Mites)	CRUSTACEA Amphipoda (Scuds)	INSECTA (2) Plecoptera (Stoneflies Nymphs)	Ephemerida (Mayfly Nymphs)	Odonata (Damselfly and Dragonfly Nymphs)	Diptera Chironomidae (Midge-fly Larvae)	Simuliidae (Blackfly Larvae)	Other (Cranefly Larvae, etc.)	Trichoptera (Caddisfly Larvae)	Coleoptera (Beetle Larvae and Adults)	Lepidoptera (Water Moth Larvae)	GASTROPODA (3) (Snails)	(Limpets)	LAMELLIBRANCHIA (Clams)	MISCELLANEOUS	TOTAL PER SAMPLE	TOTAL PER SQUARE FOOT
Columbia River at Priest Rapids	C-400	near left shore	8-13-51	Riffle 1 sq.ft.	No.							4	4		242			25							279	279
					Gms.										0.10			0.30							0.40	0.40
			9-25-51		No.			2		9		5	7		175			17			11				216	216
					Gms.								0.27		0.09			0.36			0.11				0.73	0.73
			11-19-51	Riffle 3 sq.ft.	No.					4			4	1	26			1257				20			1312	437
					Gms.									0.02	0.05			1.73				0.94			2.74	0.91
			12-3-51		No.							3			5			167			7	8			190	63
					Gms.							0.18						3.82			0.84	0.02			4.86	1.62
			2-11-52		No.								54		142			147				59			402	134
					Gms.								0.11		0.47			4.53				3.89			9.00	3.00
			9-15-52		No.								4		81			157			11	8			261	87
					Gms.								0.02		0.05			1.96			0.99	0.12			3.14	1.05
			10-13-52		No.								4		67			283		5	11	45			415	138
					Gms.								0.01		0.04			2.21		0.02	0.62	1.59			4.49	1.50
			11-10-52		No.										48			57				2			107	36
					Gms.										0.05			0.54				0.19			0.78	0.26
			12-10-52	Riffle 1 sq.ft.	No.								11		32			383		2		74			501	501
					Gms.										0.04			4.35		0.03		3.20			7.66	7.66
Number of Samples - 9				Average	No.								5		39			117				12		2		175
Number of Square Feet - 21					Gms.								0.03		0.05			0.93				0.60				1.61
			(Per Square Foot)	Max.	No.								18		242			419				74				501
					Gms.								0.27		0.16			4.39				3.20				7.66
				Min.	No.								0		2			17				0				36
					Gms.								0					0.18				0				0.24
					No.																					
					Gms.																					
Columbia River above Coyote Rapids	C-383	near left shore	9-25-51	Riffle 3 sq.ft.	No.							1	22		199			130			41	4			397	132
					Gms.								0.18		0.14			2.49			1.94				4.75	0.94
			11-6-51		No.								1		14			146			19	4			188	63
					Gms.										0.07			2.60			1.20	0.74			4.61	1.54
			12-3-51		No.			21							21			129			11	2			184	61
					Gms.			0.40							0.05			3.80			0.09	0.03			4.37	1.46
			2-11-52		No.			10					16		149			84				5	1		265	88
					Gms.			0.40					0.04		0.37			2.54				0.38	0.06		3.79	1.26
			9-15-52		No.			3					319		310	13		488				122			1755	585
					Gms.			0.01					0.29		0.74	0.01		5.99				3.24			10.28	2.35
			10-13-52		No.	1		6					208		663	5		1323				142			2348	783
					Gms.			0.01					0.32		0.49	0.01		10.45				4.98			16.26	5.42
			11-10-52		No.			3							67			59		1	2	75			207	69
					Gms.			0.01							0.08			1.06				3.86			5.01	1.67
			12-10-52	Riffle 1 sq.ft.	No.								21		34	22		327				104			508	508
					Gms.								0.01		0.04	0.01		7.27				4.56			11.89	11.89
Number of Samples - 8				Average	No.								27		89			123				24		3		266
Number of Square Feet - 22					Gms.								0.04		0.09			1.65				0.96		0.03		2.77
			(Per Square Foot)	Max.	No.								106		270			441				104				783
					Gms.								0.11		0.25			7.27				4.56				11.89
				Min.	No.								0		5			20				2				61
					Gms.								0		0.02			0.35				0.04				1.26
					No.																					
					Gms.																					
Columbia River at Hanford Ferry Crossing	C-362	Island Mid-stream	10-29-51	Riffle 3 sq.ft.	No.								3		15			19			6				43	14
					Gms.								0.01		0.01			0.04			0.22				0.28	0.02
			11-19-51		No.										5			23			17				46	15
					Gms.													0.28			1.03				1.31	0.44
			2-5-52		No.								5		78			138			16	1			238	79
					Gms.								0.01		0.19			4.30			1.32				5.82	1.94
		near left shore	9-9-52		No.	2							132		600	3		352	1	1	73	13			1177	392
					Gms.								0.18		0.33			3.21			2.01	0.09			5.82	1.94
			10-7-52		No.	8		6					59		1107	1		1372		15	11	173			3052	1017
					Gms.	0.07							0.09		1.02			9.55		.02	0.65	7.30			18.70	6.23
			11-3-52		No.	14		9					5		149			1368		11		146			1682	561
					Gms.	0.09		0.02					0.01		0.14			14.74		.05		7.69			22.74	7.58
			12-10-52	Riffle 1 sq.ft.	No.								74		50			698		3	5	46			876	876
					Gms.								0.04		0.04			10.38			0.37	2.73			13.56	13.56
Number of Samples - 7				Average	No.								15		121			208				27		4		375
Number of Square Feet - 19					Gms.								0.02		0.09			2.24				1.23		0.01		3.59
			(Per Square Foot)	Max.	No.								74		469			698				61				1317
					Gms.								0.09		0.34			10.38				2.65				13.56
				Min.	No.								0		2			6				2				14
					Gms.								0					0.01				0.07				0.09
					No.																					
					Gms.																					
					No.																					
					Gms.																					
					No.																					
					Gms.																					
					No.																					
					Gms.																					

(1) Facing Upstream
(2) Mayflies and stoneflies combined for Average, Maximum, and Minimum values
(3) Snails, limpets, and clams combined for Average, Maximum, and Minimum values

Table B-4 BOTTOM FAUNA, COLUMBIA RIVER AND TRIBUTARIES (continued)

SAMPLING DATA						ORGANISMS																					
Sampling Range	Mileage Index Number	Location of Sample (1)	Date of Sample	Type and Size of Sample		TURBELLARIA (Flatworms)	NEMATODA (Roundworms)	OLIGOCHAETA (Aquatic Earthworms)	HIRUDINEA (Leeches)	ARACHNOIDAE (Water Mites)	CRUSTACEA Amphipoda (Scuds)	INSECTA (2) Plecoptera (Stonefly Nymphs)	Ephemeridae (Mayfly Nymphs)	Odonata (Damselfly and Dragonfly Nymphs)	Diptera Chironomidae (Midge-fly Larvae)	Simulidae (Blackfly Larvae)	Other (Cranefly Larvae, etc.)	Trichoptera (Caddisfly Larvae)	Coleoptera (Beetle Larvae and Adults)	Lepidoptera (Water Moth Larvae)	GASTROPODA (3) (Snails)	(Limpets)	LAMELLIBRANCHIA (Clams)	MISCELLANEOUS	TOTAL IN SAMPLE	TOTAL PER SQUARE FOOT
Columbia River at Richland, Wash.	C-339	Island Mid-stream	8-27-51	Riffle 3 sq.ft.	No								51		513			72							639	213
					Gms								0.10		0.32			0.82							1.24	0.41
			8-27-51		No								45		508		2	50			14				622	207
					Gms								0.08		0.29			0.49			0.09				0.95	0.32
			9-4-51		No								45		931			107							1087	362
					Gms								0.10		0.42			1.98							2.50	0.83
			11-15-51		No										8			35							43	14
					Gms													0.18							0.18	0.13
			11-27-51		No								7		92			307							407	136
					Gms								0.03		0.13			4.04							4.19	1.39
		near left shore	1-29-52		No								2		110			127			1	1			241	80
					Gms										0.25			3.45			0.13	0.17			4.00	1.33
			2-5-52		No								12		57			331			16				416	139
					Gms								0.03		0.13			11.49			0.92				12.54	4.18
			9-9-52		No								40		146			442				3		4	638	213
					Gms								0.06		0.12			4.06						0.04	4.28	1.43
			10-6-52		No.	3							11		127			340			9	10			500	167
					Gms.	0.02							0.02		0.02			3.41			0.21	0.58			4.33	1.44
			11-4-52		No								4		109			545		24	4	24			710	237
					Gms.										0.13			9.93		0.08	0.44	1.66			12.17	4.06
			12-8-52	Riffle 1 sq.ft.	No	1		1					12		37			375		12	1	7			446	446
					Gms.	0.01		0.02					0.01		0.04			6.39		0.09		0.45			7.01	7.01
					No								8		85			88				3		1		189
Number of Samples - 11				Average	Gms.								0.01		0.04			1.56				0.15		0.01		1.73
Number Square Feet - 31			(Per square foot)		No								17		310			375				9				444
				Max.	Gms.								0.03		0.14			6.39				0.68				7.01
					No								0		3			12				0				14
				Min.	Gms.								0					0.15				0				0.15
					No.																					
					Gms.																					
Columbia River above Kennewick, Wash.	C-330	Near left shore	8-21-51	Riffle 1 sq.ft.	No.	1							1		93		1	39			5				140	140
					Gms.										0.20			0.34			0.15				0.89	0.89
			8-27-51	Riffle 3 sq.ft.	No.								34		523	9	2	200			8				766	255
					Gms.								0.06		0.41	0.05		3.06			0.18				3.70	1.23
			11-16-51		No.		4								32	17		67			137				257	86
					Gms.										0.04	0.05		0.37			6.06				6.52	2.17
			9-8-52		No.								33	2	180			318	1		39	14			587	196
					Gms.								0.03	0.03	0.10			2.45			0.78	0.68			4.00	1.33
					No.								6		83			62				20		4		175
Number of Samples - 4				Average	Gms.								0.01		0.08			0.64				0.77		0.01		1.91
Number Square Feet - 10			(Per square foot)		No.								11		174			186				42				253
				Max.	Gms.								0.02		0.20			1.00				2.03				3.17
					No								0		11			22				3				36
				Min.	Gms.								0		0.01			0.12				0.04				0.09
					No.																					
					Gms.																					
Columbia River below Pasco, Wash.	C-326	Island Mid-stream	8-21-51	Riffle 1 sq.ft.	No.			1					7		109			33			13				163	163
					Gms.								0.02		0.13			0.35			0.20				0.70	0.70
			8-21-51	Riffle 3 sq.ft.	No.								1		476		2	180							659	220
					Gms.										0.24			2.33							2.57	0.86
			9-4-51		No			2					54		307		6	341							732	241
					Gms.								0.12		0.16			6.27							6.57	2.19
			9-13-51		No			1							203			148			2				352	117
					Gms										0.14			3.09							3.23	1.08
			10-1-51		No.								2		217			97			21	39			376	111
					Gms.								0.12		0.12			0.72			1.70	1.19			3.85	1.27
			11-16-51		No								3		4			322			52				381	127
					Gms.													4.34			2.04				6.38	2.13
			12-26-51		No.		8								15			131							154	50
					Gms.										0.07			2.51							2.58	0.86
			1-29-52		No.										11	8		23			1				43	14
					Gms.										0.05	0.05		0.61							0.71	0.24
			2-26-52		No.								18		221			40			1	1			311	104
					Gms.								0.05		0.45			0.86				0.18			1.57	0.52
			9-8-52		No.								84		574			573			17	1			851	317
					Gms.								0.10		0.53			13.50			0.37				14.53	4.84
			10-8-52		No.	2		2					81		470			347		5	3	28			948	949
					Gms.			.02					0.14		0.70			10.06		0.08		1.32			12.60	4.22
			11-4-52		No.	10		17					6		173			720		3		44			1013	338
					Gms.	0.44		0.08					0.02		0.24			9.93		0.03		3.00			13.73	4.44
					No								8		94			138				6		5		251
Number of Samples - 12				Average	Gms.								0.02		0.08			1.45				0.38		0.02		2.03
Number of Square Feet - 34			(Per square foot)		No.								28		390			839				19				849
				Max.	Gms.								0.04		0.23			3.48				0.91				4.84
					No.								0		1			8				0				14
				Min.	Gms.								0					0.36				0				0.36
					No.																					
					Gms.																					

(1) Facing Upstream
(2) Mayflies and stoneflies combined for Average, Maximum, and Minimum values
(3) Snails, limpets, and clams combined for Average, Maximum, and Minimum values

Table B-4 BOTTOM FAUNA, COLUMBIA RIVER AND TRIBUTARIES (continued)

SAMPLING DATA						ORGANISMS																					
Sampling Range	Mileage Index Number	Location of Sample (1)	Date of Sample	Type and Size of Sample		TURBELLARIA (Flatworms)	NEMATODA (Roundworms)	OLIGOCHAETA (Aquatic Earthworms)	HIRUDINEA (Leeches)	ARACHNOIDAE Hydracarina (Water Mites)	CRUSTACEA Amphipoda (Scuds)	INSECTA (2) Plecoptera Stoneflies Nymphs)	Ephemerida (Mayfly Nymphs)	Odonata (Damselfly and Dragonfly Nymphs)	Diptera Chironomidae (Midge-fly Larvae)	Simulidae (Blackfly Larvae)	Other (Cranefly Larvae, etc.)	Trichoptera (Caddisfly Larvae)	Coleoptera (Beetle Larvae and Adults)	Lepidoptera (Water Moth Larvae)	GASTROPODA (Snails) (3)	(Limpets)	LAMELLIBRANCHIA (Clams)	MISCELLANEOUS	TOTAL IN SAMPLE	TOTAL PER SQUARE FOOT
Columbia River above Walla Walla River	C-316	Island Mid-stream	8-23-51	Riffle 3 sq.ft.	No					2					1699		2	127			14				1879	557
					Gms								0.05		0.72			2.48			0.16				3.41	1.14
			9-4-51		No								6		334		3	121			31				495	165
					Gms								0.03		0.16			2.46			0.34				2.99	1.00
			9-13-51		No								3		312			39			49				403	134
					Gms										0.16			0.64			0.44				1.24	0.41
		near right shore	11-16-51		No	16							37		245			328			3	10			639	213
					Gms	0.24							0.14		0.28			4.52				0.05			5.03	1.94
			11-28-51		No	29	5	4	2				18		24		3	481	2		5	12			585	195
					Gms	0.18			0.08				0.08		0.05			7.64			0.18	0.92			9.18	3.06
			12-12-51		No								19		3			126			2	3			153	51
					Gms								0.11		0.01			1.92			0.05	0.25			2.34	0.78
			1-10-52		No	1			3		1				10			177			3	3			199	66
					Gms				0.15		0.02				0.01			1.98			0.15				2.31	0.77
			2-20-52		No	2		8	2			1	47		20			263			4	11			358	119
					Gms				0.25			1.00	0.22					3.43			0.05	0.20			5.15	1.72
		near left shore	11-17-52		No	15						1	50		125	2	1	699	3		10	59			965	322
					Gms	0.10						1.18	0.17		0.20			5.05			0.48	3.15			10.37	3.46
					No								8		95			87				8		4		202
Number of Samples - 9				Average	Gms								0.11		0.06			1.12				0.27		0.04		1.60
Number Square Feet - 27					No								17		509			233				23				557
			(Per square foot)	Max.	Gms								0.45		0.24			2.56				1.22				3.46
					No								0		1			13				2				51
				Min.	Gms								0					0.21				0.08				0.78
					No																					
					Gms																					
Columbia River at Juniper Canyon	C-306	Island Mid-stream	8-15-51	Riffle 1 sq.ft.	No					1			2		155			16	2		1				177	177
					Gms								0.02		0.08			0.38			0.05				0.47	0.47
			8-28-51	Riffle 3 sq.ft.	No				1	3			27	1	252			78			24				316	105
					Gms								0.05		0.10			1.08			0.19				1.42	0.47
		near right shore	11-14-51		No								40		54			304		2	120		1		522	174
					Gms								0.11		0.05			4.11			4.76				9.03	3.01
			11-28-51		No								7		20			215			49	1			292	97
					Gms								0.05		0.03			4.26			2.38				6.72	2.24
			12-12-51		No		1						7		28			80	2		175				346	115
					Gms								0.02		0.09			0.60			4.59				5.30	1.77
			1-10-52		No								10		191			68		1	105	41			417	139
					Gms								0.05		0.13			0.61			1.53	1.76			4.10	1.37
			2-29-52		No								9		111			564		11	37	35			767	256
					Gms								0.02		0.13			4.12		0.03	2.00	2.57			8.87	2.96
		near left shore	11-17-52		No	3	2						16		329			328	1	11	85	172	1		2248	749
					Gms	0.04							0.01		0.41			13.72		0.04	3.89	11.97	.06		[illegible]	30.05
					No								5		52			134				38		2		231
Number of Samples - 8				Average	Gms								0.02		0.05			1.31				1.62		.01		3.01
Number Square Feet - 22					No								13		110			543				86				769
			(Per square foot)	Max	Gms								0.04		0.14			4.58				5.29				10.05
					No								1		7			16				1				97
				Min	Gms								0.01		0.01			0.20				0.05				0.47
					No																					
					Gms																					
Columbia River above McNary Dam	C-297	Near left shore	10-2-51	Riffle 3 sq.ft.	No								6		89			180			76	9	1		361	120
					Gms										0.07			1.47			2.30				3.84	1.28
			11-7-51	Riffle 6 sq.ft.	No								4		35			225		2	131	43			441	73
					Gms										0.04			2.47			3.11	1.85			8.47	1.41
			11-20-51	Riffle 5 sq.ft.	No													177			25	93			295	98
					Gms													4.15			1.10	5.30			10.55	3.52
			1-10-52		No										12			28			38	28			106	35
					Gms										0.06			0.53			1.67	2.27			4.53	1.51
			1-30-52		No		2	2					2		14			25			43	23			111	37
					Gms		0.01	0.01							0.05			0.52			1.68	2.01			4.28	1.43
			2-13-52		No								11		161			126			52	61			411	137
					Gms								0.03		0.22			2.43			3.13	4.62			10.43	3.48
			3-12-52		No								3		88			101			14	9	1		216	72
					Gms								0.03		0.22			2.58			0.62	1.05			4.54	1.51
			9-10-52		No								28		211			401			29	303			972	324
					Gms								0.06		0.21			3.15			0.84	7.15			11.41	3.80
			10-16-52		No								13		48			548		7	22	246			886	295
					Gms								0.02		0.04			3.71		0.01	0.83	11.12			15.73	5.24
			11-5-52		No										10			364		16	20	192			602	201
					Gms										0.01			3.53		0.06	0.96	10.21			14.77	4.92
			12-9-52	Riffle 1 sq.ft.	No										52			112		33	5	128			320	320
					Gms										0.11			1.29		0.08	0.16	8.39			10.03	10.03
					No								2		23			72				49		2		148
Number of Samples - 11				Average	Gms								0.01		0.03			0.81				2.21		0.01		3.08
Number Square Feet - 34					No								9		70			183				133				324
			(Per square foot)	Max.	Gms								0.02		0.11			1.29				8.55				10.03
					No								0		0			8				8				35
				Min.	Gms								0		0			0.17				0.60				1.41

(1) Facing Upstream
(2) Mayflies and stoneflies combined for Average, Maximum, and Minimum values
(3) Snails, limpets, and clams combined for Average, Maximum, and Minimum values

Table B-4 BOTTOM FAUNA, COLUMBIA RIVER AND TRIBUTARIES (continued)

SAMPLING DATA						ORGANISMS																				
Sampling Range	Mileage Index Number	Location of Sample (1)	Date of Sample	Type and Size of Sample		TURBELLARIA (Flatworms)	NEMATODA (Roundworms)	OLIGOCHAETA (Aquatic Earthworms)	HIRUDINEA (Leeches)	ARACHNOIDAE Hydracarina (Water Mites)	CRUSTACEA Amphipoda (Scuds)	INSECTA Plecoptera (Stonefly Nymphs) (2)	Ephemerida (Mayfly Nymphs)	Odonata (Damselfly and Dragonfly Nymphs)	Diptera Chironomidae (Midge-Midge)	Simuliidae (Blackfly Larvae)	Other (Crane fly Larvae, etc.)	Trichoptera (Caddisfly Larvae)	Coleoptera (Beetle Larvae and Adults)	Lepidoptera (Water Moth Larvae)	GASTROPODA (Snails) (3)	(Limpets)	LAMELLIBRANCHIA (Clams)	MISCELLANEOUS	TOTAL IN SAMPLE	TOTAL PER SQUARE FOOT
Columbia River at Paterson, Wash.	C-278	Island Mid-stream	8-29-51	Riffle 3 sq.ft.	No.						7		11		324			25			32	1			404	135
					Gms.								0.05		0.19			0.64			0.77				1.69	0.56
			9-22-51		No.						3		19		191			44			54	1			312	104
					Gms.								0.05		0.14			0.91			0.69				1.83	0.61
			10-3-51		No.								36		164			64			38				302	101
					Gms.								0.10		0.07			0.56			0.65				1.32	0.44
			11-7-51	Riffle 6 sq.ft.	No.		3				33		34		186			212			153	3			544	91
					Gms.						0.16		0.16		0.16			2.03			4.41	0.14			7.04	1.14
			11-28-51	Riffle 3 sq.ft.	No.		3	2			15		40		12			636		2	110	4			824	275
					Gms.						0.31		0.22		0.20			7.85			5.09	0.66			14.37	4.79
			3-13-52		No.						6		4		51			99			58	4			222	74
					Gms.						0.01		0.02		0.12			2.51			3.80	0.42			6.88	2.29
			9-25-52		No.						8		15		80			391			80	13			587	196
					Gms.						0.05		0.03		0.05			0.92			1.26	0.45			2.76	0.92
			10-25-52		No.						11		2		22			521		1	130	11			698	233
					Gms.						0.04		0.01		0.03			2.72			5.64	0.83			9.27	3.09
			11-6-52		No.						20		1		57			124			15	21			238	79
					Gms.						0.04		0.01		0.08			1.67			0.95	3.43			6.18	2.03
					No.								5		35			77				26		3		146
Number of Samples - 9				Average	Gms.								0.02		0.03			0.71				1.04		0.02		1.82
Number Square Feet - 50					No.								13		108			213				47				275
			(Per square foot)	Max.	Gms.								0.07		0.07			2.63				2.16				4.79
					No.								0		4			10				11				79
				Min.	Gms.								0		0.01			0.17				0.23				0.44
					No.																					
					Gms.																					
					No.																					
					Gms.																					
Columbia River All Samples			(Per square foot)	Average	No.								8		78			109				21		3		211
					Gms.								0.03		0.07			1.27				0.90				2.27
					No.																					
Number of Samples - 35					Gms.																					
Number Square Feet - 250					No.																					
					Gms.																					
					No.																					
					Gms.																					
					No.																					
					Gms.																					
ADDITIONAL SAMPLES TAKEN UNDER ADVERSE WATER CONDITIONS -- NOT INCLUDED IN PREVIOUSLY LISTED AVERAGES																										
					No.																					
					Gms.																					
Columbia River at Priest Rapids	C-480	near left shore	11-6-51	Riffle 3 sq.ft.	No.										8										8	
					Gms.										0.01										0.01	
					No.																					
					Gms.																					
Columbia River at Coyote Rapids	C-383	near left shore	1-15-52		No.			4					1		3	1					19				27	
					Gms.			0.02													1.03				1.05	
" "	"	"	1-28-52		No.			9					2		2			2			28				43	
					Gms.			0.07													1.67				1.74	
Columbia River above Kennewick	C-330	near left shore	10-30-51		No.			1					2		30	14		8			134	2			191	
					Gms.										0.12			0.03			4.24				4.39	
			10-30-51		No.										9	14		4			12				39	
					Gms.										0.03	0.04		0.03			0.66				0.79	
Columbia River below Pasco & above Snake River	C-326	Island Mid-stream	10-30-51		No.		12								4						2				18	
					Gms.																0.01				0.01	
					No.																					
					Gms.																					
		near left shore	1-23-52		No.										1						4				5	
					Gms.										0.01						0.16				0.18	
Columbia River at Juniper Canyon	C-306	near right shore	1-25-52		No.		1														96				97	
					Gms.																2.39				2.39	
			1-23-52		No.			12							3			1			22				37	
					Gms.			0.1													0.08				0.19	
Columbia River above McNary Dam	C-297	near left shore	9-25-51	Riffle 1 sq.ft.	No.			6					3		18			9			2				38	
					Gms.													0.20			.01				0.21	
			10-25-51	Riffle 3 sq.ft.	No.			4					1		11			36		2	26	2			82	
					Gms.			0.04										0.26			0.94				1.26	
Columbia River at Paterson, Wash.	C-278	Island Mid-stream	1-25-52		No.			1							1			1			7				10	
					Gms.													0.02			0.34				0.36	
					No.																					
					Gms.																					
					No.																					
					Gms.																					
					No.																					
					Gms.																					
					No.																					
					Gms.																					

(1) Facing Upstream
(2) Stoneflies and stoneflies combined for Average, Maximum, and Minimum values
(3) Snails, limpets, and clams combined for Average, Maximum and Minimum values

Table B-4 BOTTOM FAUNA, COLUMBIA RIVER AND TRIBUTARIES (continued)

SAMPLING DATA						ORGANISMS																					
Sampling Range	Mileage Index Number	Location of Sample (1)	Date of Sample	Type and Size of Sample		TURBELLARIA (Flatworms)	NEMATODA (Roundworms)	OLIGOCHAETA (Aquatic Earthworms)	HIRUDINEA (Leeches)	ARACHNOIDAE Hydrocarina (Water Mites)	CRUSTACEA Amphipoda (Scuds)	INSECTA Plecoptera (Stonefly Nymphs) (2)	Ephemerida (Mayfly Nymphs)	Odonata (Damselfly and Dragonfly Nymphs)	Diptera Chironomidae (Midge-fly Larvae)	Simuliidae (Blackfly Larvae)	Other (Cranefly Larvae, etc.)	Trichoptera (Caddisfly Larvae)	Coleoptera (Beetle Larvae and Adults)	Lepidoptera (Water Moth Larvae)	GASTROPODA (Snails) (3)	(Limpets)	LAMELLIBRANCHIA (Clams)	MISCELLANEOUS	TOTAL IN SAMPLE	TOTAL PER SQUARE FOOT
Yakima River at Kiona, Wash.	CY-346	near left shore	8-16-51	Riffle 1 sq.ft.	No	89		86					155		141	19	6	98	54	14	49	8			716	716
					Gms.	0.29		0.28					0.57		0.07			0.55	0.16		0.75				2.64	2.64
			8-23-51		No	135		70					121		619	5	19	69	46	7	50	16			957	957
					Gms.	0.71							0.21		0.24			0.09			2.02				3.27	3.27
			8-31-51	Riffle 2 sq.ft.	No	128		33	1				131	13	523	22	3	46	86	15	261	135			749	749
					Gms.	0.62			0.59				0.49	0.49	0.28			0.34			9.69				12.06	6.23
			9-5-51	Riffle 1 sq.ft.	No	195		46					163		337			129	28	19	21	41			890	890
					Gms.	0.70							0.46		0.24			0.31			2.96				4.72	4.72
			10-10-51		No	52		140					13	6	36	2	4	16		3	122	17			611	611
					Gms.	0.12		0.31					0.01	0.08	0.03			0.02			2.83	0.34			3.74	3.74
Number of Samples - 5				Average	No								97		259			59				120		209		744
					Gms.								0.29		0.14			0.23				3.18		0.71		4.47
Number Square Foot - 6			(Per square foot)	Max.	No								163		419			129				198				957
					Gms.								0.57		0.24			0.55				4.85				6.23
				Min.	No								13		36			16				57				411
					Gms.								0.01		0.03			0.02				0.75				2.64
					No.																					
					Gms.																					
Yakima River at Enterprise, Wash.	CY-343	near right shore	8-16-51	Riffle 1 sq.ft.	No			10					94	2	132		3	42	32		1				316	316
					Gms.								0.25		0.10			0.2							0.56	0.56
			8-23-51		No	40		5					67	6	101		2	57	16						274	274
					Gms.	0.49		0.20					0.15	0.40	0.10			0.44							1.69	1.69
			8-31-51		No	39	2	4					125	5	521	1	1	48	19	4		2			761	761
					Gms.	0.26							0.30		0.32			0.12							1.00	1.00
			9-7-51		No	24							375	10	490	18		250	43	7		4			821	821
					Gms.	0.16							0.90	0.85	0.34			0.92							3.17	3.17
			10-10-51		No	2		4					28	2	30	20	2	186		3					277	277
					Gms.	0.03							0.08	0.06	0.04	0.04		2.06		0.01					2.32	2.32
			11-7-51		No						1		12		89	212		37							351	351
					Gms.								0.05		0.16	0.85		0.41							1.47	1.47
			1-10-52	Riffle 2 sq.ft.	No								22	2	49	94		206	3						373	186
					Gms.								0.14	0.03	0.27	0.56		4.73							5.73	2.86
			6-23-52		No	23		7					330	1	232	3		206	39						841	421
					Gms.	0.11		0.03					1.26		0.28			3.61	0.04						5.33	2.67
			9-9-52	Riffle 1 sq.ft.	No	11							304	5	336	18		443	6	11		17			1153	1153
					Gms.	0.04							0.62	0.38	0.28	0.04		0.49				0.01			1.86	1.86
			11-5-52		No	64		3					37		134	50		284	2	2					576	576
					Gms.	0.29		0.04					0.12		0.27	0.08		3.62							4.42	4.42
					No								315		176			147				2		73		513
Number of Samples - 10				Average	Gms.								0.32		0.18			1.30						0.41		2.29
Number Square Foot - 12			(Per square foot)	Max.	No								375		521			443				17				1153
					Gms.								0.90		0.34			3.62				0.01				4.42
				Min.	No								11		25			37				0				186
					Gms.								0.05		0.16			0.12				0				0.56
					No.																					
					Gms.																					
Yakima River at Richland Highway Bridge	CY-339	near left shore	8-15-51	Riffle 1 sq.ft.	No	5							165		512	21	1	117	10	4	5	8			847	847
					Gms.	0.11							0.62		0.44			1.42			0.14				2.51	2.51
			9-7-51		No	19							113	2	649	58		56			5	14			916	916
					Gms.	0.22							0.37		0.53			0.45			0.29				1.78	1.78
			10-10-51	Riffle 2 sq.ft.	No	60							112	3	196	26		419	1	5	2	16			840	420
					Gms.	0.01							0.13		0.15			5.86				0.13			6.51	3.26
			11-20-51	Riffle 3 sq.ft.	No		12	8					8		61	919		87							1095	365
					Gms.		0.06	0.04					0.06		0.23	5.52		1.78							7.71	2.57
			1-20-52	Riffle 2 sq.ft.	No	34		8					90	3	118	200		418	5	3	1	11			891	446
					Gms.	0.23							0.11		0.29	0.94		4.07				0.13			5.77	2.89
			3-12-52	Riffle 2 sq.ft.	No								62		512	3		48							647	324
					Gms.								0.31		1.84	0.02		1.45							3.62	1.81
			5-5-52		No	18		9				1	182	5	859		8	706	18	17					1823	912
					Gms.	0.07		0.05					0.47	0.21	0.77			6.86		0.18					8.61	4.31
			7-23-52	Riffle 1 sq.ft.	No								340	1	887	12		265	11	7					1123	1123
					Gms.								1.24		0.71	0.02		2.16	0.05						4.18	4.18
			10-29-52	Riffle 2 sq.ft.	No	98		2					179		258	43		2320	7	34		2			2863	1431
					Gms.	0.46							0.62		0.23	0.05		17.70		0.23		0.01			19.19	9.60
					No								78		228			272				4		106		688
Number of Samples - 9				Average	Gms.								0.23		0.32			2.16				0.04		0.53		3.73
Number Square Foot - 36			(Per square foot)	Max.	No								340		649			1120				19				1421
					Gms.								1.24		0.53			8.85				0.25				9.60
				Min.	No								3		28			29				0				334
					Gms.								0.02		0.08			0.42				0				1.78
					No																					
					Gms.																					
Yakima River All Samples					No	28		13					94	2	215	51	1	190	13	5		24		1		637
				Average	Gms.	0.14		0.03					0.27	.07	0.24	0.24		1.76	0.01	0.02		0.37		0.03		3.37
			(Per square foot)		No																					
Number of Samples - 24				Max.	Gms.																					
Number Square Foot - 36					No.																					
				Min.	Gms.																					

(1) Facing Upstream
(2) Mayflies and stoneflies combined for Average, Maximum, and Minimum values
(3) Snails, limpets, and clams combined for Average, Maximum, and Minimum values

Table B-4 BOTTOM FAUNA, COLUMBIA RIVER AND TRIBUTARIES (continued)

SAMPLING DATA						ORGANISMS																				
Sampling Range	Mileage Index Number	Location of Sample (1)	Date of Sample	Type and Size of Sample		TURBELLARIA (Flatworms)	NEMATODA (Roundworms)	OLIGOCHAETA (Aquatic Earthworms)	HIRUDINEA (Leeches)	ARACHNOIDAE Hydracarina (Water Mites)	CRUSTACEA Amphipoda (Scuds)	INSECTA (2) Plecoptera (Stoneflies, Nymphs)	Ephemerida (Mayfly Nymphs)	Odonata (Damselfly and Dragonfly Nymphs)	Diptera Chironomidae (Midge-fly Larvae)	Simuliidae (Blackfly Larvae)	Other (Cranefly Larvae, etc.)	Trichoptera (Caddisfly Larvae)	Coleoptera (Beetle Larvae and Adults)	Lepidoptera (Water Moth Larvae)	GASTROPODA (3) (Snails)	(Limpets)	LAMELLIBRANCHIA (Clams)	MISCELLANEOUS	TOTAL SAMPLE	TOTAL PER SQUARE FOOT
Snake River at Page, Wash.	CS-342	Island Mid-stream	8-17-51	Riffle 3 sq.ft.	No								79		81			660			9	1			820	273
					Gms								1.21		0.09			2.82			0.03				4.09	1.36
Snake River near mouth	CS-325		8-17-51	Riffle 1 sq.ft.	No			2					4		9			36			1	5			57	57
					Gms													0.14				0.02			0.16	0.16
		near left shore	1-23-52		No		5	5					10		27			10							57	57
					Gms			0.01					0.06		0.08			0.20							0.35	0.35
			10-8-52	Riffle 2 sq.ft.	No			2					98		43			[illegible]		1					2367	1184
					Gms								0.33		0.03			7.75							8.11	4.06
			11-6-52	Riffle 1 sq.ft.	No		3						58		99			996		1		1			1157	1157
					Gms								0.25		0.09			7.10							7.46	7.46
Number of Samples - 5 Number Square Feet - 6				Average	No								31		32			449				2		2		532
					Gms								0.25		0.03			2.24				.01				2.53
			(Per square foot)	Max.	No								58		99			[illegible]				6				1157
					Gms								0.40		0.09			7.10				.02				7.46
				Min.	No								4		9			10				0				57
					Gms													0.14				0				0.16
					Gms																					
Walla Walla River at Old Highway Crossing	CWw-322	near left shore	8-15-51	Riffle 1 sq.ft.	No			3				5	167	1	146	24	3	1172	40						1560	1560
					Gms								0.70		0.10			12.48							13.28	13.28
			10-2-51		No							1	68	27	12	4		102	4	19		14			251	251
					Gms								0.23	0.28				1.30		0.05		0.06			1.92	1.92
			6-25-52		No								158		76	24		[illegible]	11						954	954
					Gms								0.49		0.05	0.05		3.87	0.02						4.48	4.48
			7-23-52		No								166		111	12	2	924	50	12			1		1278	1278
					Gms								0.28		0.10			7.67	0.06	0.07					8.23	8.23
			8-13-52		No								246		252	2		789	17						1306	1306
					Gms								0.33		0.25			3.40	0.02						4.00	4.00
			10-30-52		No			7					131	7	186	651		1577	24	17					2600	2600
					Gms			0.01					0.49	0.26	0.22	0.34		15.20	0.02	0.04					16.58	16.58
			11-17-52		No			4					114		353	[illegible]	2	[illegible]	206	17					5262	5262
					Gms								0.15		0.06	1.26	0.15	40.08	0.13	0.10					42.07	42.07
				Average	No			2					151	5	162	320	1	1188	50	9		2		66		1983
					Gms								0.38	0.06	0.22	0.24	0.02	11.95	0.06	0.04		0.01		.16		13.02
Number of Samples - 7 Number Square Feet - 7			(Per square foot)	Max.	No								246		353			[illegible]				16				5262
					Gms								0.70		0.06			40.08				0.06				42.07
				Min.	No								68		12			102				0				251
					Gms								0.15					1.30				0				1.92
					No																					
					Gms																					
					No																					
					Gms																					
ADDITIONAL TRIBUTARY SAMPLES TAKEN UNDER ADVERSE WATER CONDITIONS (NOT INCLUDED IN AVERAGES)																										
Snake River at Page, Wash.	CS-342	Island Mid-stream	10-25-51	Riffle 3 sq.ft.	No										1										1	
					Gms										0.01										0.01	
			11-28-51		No		1	1							14						3				18	
					Gms										0.03						0.06				0.09	
			3-19-52		No								4					5							9	
					Gms								0.03					0.06							0.09	
Walla Walla River at Old Highway Bridge	CWw-322	near left shore	3-19-52		No								39		2			39							76	
					Gms								0.24					0.98							1.22	

(1) Facing Upstream
(2) Mayflies and stoneflies combined for Average, Maximum and Minimum values
(3) Snails, limpets, and clams combined for Average, Maximum and Minimum values

Table B-5 RELATIVE ABUNDANCE OF JUVENILE FISH SEINE COLLECTIONS

Sampling Range	Date of Sample	Relative Number of Fish A = over 15; B = 11-15; C = 6-10; D = 0-5									
		Salmon	Suckers	Squawfish	Shiners	Chiselmouth	Chubs	Dace	Sticklebacks	Bass and Sunfish	Sculpins
	(1952)										
C-400	2-11		A	C	B						
	2-25		D	A	D		D	D	D		D
	4-16	D	D	A	A		C		D		
	4-28	D	C	B	A		C	D			D
	5-12		D	B	A	D	C	D	D		D
	6-2	D	A	D	A		D	A	D		B
	7-28			A	A						
	8-11			B	A		D				
	9-15		D	A	A		D				D
	10-13		A	D	D	B	D				
	11-10		C	C	B		D				D
	12-10		A	A	A						C
	(1953)										
	1-19		C	B	A						D
	2-25		D	C	B						
	3-17	A			D						
	(1952)										
C-385	6-2		A	C			B	D			
	8-11		A	A			C		D		
	(1952)										
C-383	1-28		D	D	A		D		D		

Table B-5 RELATIVE ABUNDANCE OF JUVENILE FISH SEINE COLLECTIONS

Sampling Range	Date of Sample	Relative Number of Fish A = over 15; B = 11-15; C = 6-10; D = 0-5									
		Salmon	Suckers	Squawfish	Shiners	Chiselmouth	Chubs	Dace	Sticklebacks	Bass and Sunfish	Sculpins
C-383	2-11		D	A	A	D			D		
(cont'd)	2-25		D	D	A			D			
	3-10			D	A						D
	3-24			A	A		C				C
	4-16	A	D	A	C		C				
	4-28	C	D	B	D			B			D
	5-12			A	B			D	D		D
	6-2		D	C	B			A	D		B
	7-28				A						
	8-11		D	B	A				C		D
	9-15		D	C	A			D			D
	10-13				A						
	11-10				A						
	12-10				A						
	(1953)										
	1-19				D				D		D
	2-25				A						
	3-17	A	D	C	A						
	(1952)										
C-362	1-22		D	A	A	D				D	
	2-5		D	A	A						
	2-18			B	A		A				
	3-3			C	A		A				

Table B-5 RELATIVE ABUNDANCE OF JUVENILE FISH SEINE COLLECTIONS

Sampling Range	Date of Sample	Relative Number of Fish A = over 15; B = 11-15; C = 6-10; D = 0-5									
		Salmon	Suckers	Squawfish	Shiners	Chiselmouth	Chub	Dace	Sticklebacks	Bass and Sunfish	Sculpins
C-362	3-17	D		A	A		B		D		
(cont'd)	4-16	A	C	A	A		D	D	D		
	4-22	A	D	A	A		D	D	D		
	5-6	A	D	D	B			D			
	5-26		A	C	A		A				
	6-16		C	B	A	D		D	D	D	
	7-8		D	A	B			C	D		
	8-4		B	A	A	D					
	9-9		D	A	B	D	B		A		
	10-7		B	A	A	D	D	A			
	11-3		D	B	A	D	A	D			
	(1953)										
	1-5			A	A		D		D		
	2-10			C	A		B				
	3-25	A			A						
	(1952)										
C-339	1-22		D	A	D	D	D			D	
	2-5		D	A		D				D	
	2-18			A	D					D	
	3-3			A	B						
	3-10		D	A	A		D				
	4-7			A	A	B	D			D	D
	4-22	B	A	A	A		D	D			C

Table B-5 RELATIVE ABUNDANCE OF JUVENILE FISH SEINE COLLECTIONS

Sampling Range	Date of Sample	Relative Number of Fish A = over 15; B = 11-15; C = 6-10; D = 0-5									
		Salmon	Suckers	Squawfish	Shiners	Chiselmouth	Chubs	Dace	Sticklebacks	Bass and Sunfish	Sculpins
C-339	5-5	A	C	A	B	D					
(cont'd)	5-12	A	D	A	A			D		D	
	6-16		D	A	C			B	B		C
	7-8			A	A						
	8-4		D				A		A		B
	9-9		C	D	A			B	C	C	D
	10-6		A	B	C	C			B	A	C
	11-4		D	A	B			D	D		C
	12-3			D	B						D
	(1953)										
	1-6			D	A						
	2-10		D	C	C						
	3-16	C		C	C						
	(1952)										
C-330	1-21		D	A	A	D	D				
	2-4			A	A	A	D				
	2-18		D	A	A	A	A				
	3-3			B	A	C	A				
	3-10			A	A	D	A				
	4-8	D		B	A		D				
	4-21	A	C	C	A	D				C	D
	5-5	C		A	B						D
	6-9		C	A	A		D	D			

Table B-5 RELATIVE ABUNDANCE OF JUVENILE FISH SEINE COLLECTIONS

Sampling Range	Date of Sample	Relative Number of Fish A = over 15; B = 11-15; C = 6-10; D = 0-5									
		Salmon	Suckers	Squawfish	Shiners	Chiselmouth	Chubs	Dace	Sticklebacks	Bass and Sunfish	Sculpins
C-330	8-5		A	B						B	
(cont'd)	9-8		D	B	B		C	B	D	A	C
	12-8			A	A						D
	(1952)										
C-326	1-21			A	A	D				D	
	2-4			A	A					D	
	2-18			A	A	C				D	
	3-3			A	A	C					
	3-17	D		A	A	D		D	D	D	
	4-8	D		A	A	B					
	4-21	C	B	A	A	A	D	D		D	D
	5-5	B	C	A	B	B					D
	5-26			D	A	D					
	6-9		A	A		C		C			
	7-15			A	A	B		C			D
	8-5			B				D	D		
	9-8			A	A	D		B		B	
	10-8		D	A	D				A	A	C
	11-4			A	B			C	D		
	(1953)										
	3-26	B		B	A	C					

Table B-5 RELATIVE ABUNDANCE OF JUVENILE FISH SEINE COLLECTIONS

Sampling Range	Date of Sample	Relative Number of Fish A = over 15; B = 11-15; C = 6-10; D = 0-5									
		Salmon	Suckers	Squawfish	Shiners	Chiselmouth	Chubs	Dace	Sticklebacks	Bass and Sunfish	Sculpins
	(1952)										
C-316	1-23			A	A	B					
	2-6		B	A	A	C		C			D
	2-20		D		D			D			D
	3-5		D	D	A			D			C
	3-19		D	C	A			D			
	4-9	D	B	D	A	D		A			B
	4-23			D	A	D		B			C
	5-7	D	C	A	A	B		C		D	
	8-13			C	A	D		D			
	(1952)										
C-306	1-23			A	A	C					
	2-6		D	A	A	A				D	
	2-20			B	A	B	D				
	3-5			A	A	A	D				
	3-19		B	A	A	C	D				
	4-9		D	A	A	B				D	
	4-23		D	A	A	C					D
	5-7	D	D	A	A	C		D		D	
	6-18		A	B		B		D			
	7-9			A	B	A		D			
	8-6			A	A	D	C	D			
	8-13		C	A	A				A	C	
	9-10		D	A					D		

Table B-5 RELATIVE ABUNDANCE OF JUVENILE FISH SEINE COLLECTIONS

Sampling Range	Date of Sample	Relative Number of Fish A = over 15; B = 11-15; C = 6-10; D = 0-5									
		Salmon	Suckers	Squawfish	Shiners	Chiselmouth	Chubs	Dace	Sticklebacks	Bass and Sunfish	Sculpins
C-306	10-29		D	B				D			C
(cont'd)	11-17			C				C			B
	12-8		D	A	C				D		C
	(1952)										
C-297	1-30		D	B	A	D			D		D
	2-13		D	A	A	A	D		D		
	2-27		D	A	A	B	D				D
	3-12		D	B	A	D	D	D			C
	3-26		D	A	A	B					D
	4-23		B	A	B	D		D		D	C
	4-30	D	B	A	A	C	D	C			B
	5-14	C	B	A	D	C		D			C
	6-18		C	A	A	C		D			
	7-9		D	A	C	A				D	D
	8-6		A	A	D	A	D				
	9-10		B	A	B	C	C		C	B	
	10-15		D	A	A	D		C			D
	11-5			A	A						
	12-9		D	A	C	A					
	(1953)										
	1-7			A	B			D		D	
	3-5			C	A	B					

Table B-5 RELATIVE ABUNDANCE OF JUVENILE FISH SEINE COLLECTIONS

Sampling Range	Date of Sample	Relative Number of Fish A = over 15; B = 11-15; C = 6-10; D = 0-5									
		Salmon	Suckers	Squawfish	Shiners	Chiselmouth	Chubs	Dace	Sticklebacks	Bass and Sunfish	Sculpins
	(1952)										
C-278	1-30			B	A						
	2-13			A	A			D			D
	2-27			B	A	B	A				
	3-12		D	A	A	D	D				D
	3-26			B	A	B					
	4-23	D	B	A	A	D		C			B
	4-30			B	A	D	D			D	D
	5-14		B	A	B	B		D		A	
	6-18		C	A	A	A		C			
	7-9		B	A	A	B		B			
	8-6		C	A	D	A	D			B	
	9-10		C	A	A	B	D	B		B	
	10-15		D	A	A	B		B		B	
	11-5			A	A	D		B		D	
	12-17			A	A						
	(1953)										
	2-11			A	A	B					
	3-5	D		C	A	D					
	(1952)										
Yakima	1-30			A	A	D		D		D	
River	2-26		D	A	A	C		D			
	3-12			A	A	A	D			D	

Table B-5 RELATIVE ABUNDANCE OF JUVENILE FISH SEINE COLLECTIONS

Sampling Range	Date of Sample	Relative Number of Fish A = over 15; B = 11-15; C = 6-10; D = 0-5									
		Salmon	Suckers	Squawfish	Shiners	Chiselmouth	Chubs	Dace	Sticklebacks	Bass and Sunfish	Sculpins
Yakima	3-26	D		A	A	C		D			
River	4-30	C	D	A	B	B		A		D	
(cont'd)	5-7			A		C		D		D	
	6-23			B		D		B		D	
	7-23			B	C	C				C	
	9-9			A		C		C		A	
	10-29			B						C	
	11-5		D	B	C	C				D	
	(1953)										
	3-16			B	D	D				D	
	(1952)										
Snake	1-23			C	A	D					
River	2-6		C	B	B	C		D			D
	3-5			B	A		B				
	3-19		D	A	A	A		B			D
	4-30			D	D	D		D			C
	6-25			C	C	B		D			
	7-23		D	A	D	B	D			D	
	8-5			A		A					
	11-4			A	A	D					
	(1953)										
	3-26	D	D	B	A	D		D			D

Table B-5 RELATIVE ABUNDANCE OF JUVENILE FISH SEINE COLLECTIONS

Sampling Range	Date of Sample	Relative Number of Fish A = over 15; B = 11-15; C = 6-10; D = 0-5									
		Salmon	Suckers	Squawfish	Shiners	Chiselmouth	Chubs	Dace	Sticklebacks	Bass and Sunfish	Sculpins
	(1952)										
Walla	3-5		D	B	D	A		C			
Walla	4-30		D	D	D	C					
River	5-14		B	B	C	B					
	6-25	D	D	B	A	B		B			
	7-23		B	D	B	A		B		D	
	8-13			B	A	A		B		D	
	10-29							A			
	11-17		D	D		C		B			

Table B-6 - ADULT FISH -- GILL NET CATCHES, RANGE C-362

DATE / Number of Samples*		June 1952	July 1952	Sept 1952	Oct 1952	Nov 1952	Dec 1952	Jan 1953	Mar 1953	Total
		2	4	1	3	2	1	2	1	
SPECIES										
Blueback Salmon	Number	5	3							8
	Length,"	18-20	21							18-21
Whitefish	Number	3							1	4
	Length,"	13-16							13	13-16
c.s. Sucker	Number	11	13	9	36	9	6	1	5	90
	Length,"	13-18	17-20	16-20	17-19	18	17-24	14-15	18-22	13-24
f.s. Sucker and Mountain Sucker	Number	1	8		4	1			3	17
	Length,"	17	13-20		18	18			18	13-20
Carp	Number		1		3	8	2		2	16
	Length, "		27		12-20	18-20	18-20		20	12-20
Chub	Number	1								1
	Length, "	12								12
Chiselmouth	Number	1	1							2
	Length, "	12	12							12
Squawfish	Number	20	9	1	2	5	2	3	8	50
	Length,"	12-18	14-19	8	18	18	17	17-19	15-17	12-19
Small-mouth Bass	Number		3	5	9	4	1			22
	Length,"		13-16	12-19	13-19	14-18	17			12-19
Yellow Perch	Number				2					2
	Length,"				13					13

* Each set represents an overnight bottom set with a gill net containing 25 yards of 1" mesh, 50 yards of 2" mesh and 50 yards of 3" mesh net. Most of the sets were in water from 6 to 15 feet deep and were in fairly quiet water near the edge of the main channel.

Table **B-7** RADIOACTIVITY OF AQUATIC ORGANISMS

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY in 10^{-7} μc/gram												
				PLANTS						ANIMALS						
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample	PLANKTON	FILAMENTOUS ALGAE Cladophora sp	Stigeoclonium sp	Spirogyra sp	Ulothrix sp	Miscellaneous	SPONGE - PORIFERA	AQUATIC INSECTS Caddisfly larvae (Trichoptera)	Other insect larvae (See footnotes)	MOLLUSKS Snails-whole (s-soft parts only)	Limpets-whole (s-soft parts only)	CRUSTACEANS Crayfish (Astacus trowbridgii)	MISCELLANEOUS (See footnotes)
Columbia River above Trinidad, Wash.	C-445	Right Shore	7-12-63	232 ± 93	48 ± 17						9 ± 22	34[W] ± 21	8 ± 32	-5 ± 37	27 ± 17	
				236 ± 119	33 ± 8						9 ± 10	11[W] ± 17	10 ± 35	44 ± 36	6 ± 7	
				90 ± 390							7 ± 19	36[W] ± 36	13 ± 17	-13 ± 17	14 ± 14	
				510 ± 210							1 ± 10		-1 ± 15	-30 ± 16	11 ± 7	
															9 ± 12	
															9 ± 11	
Columbia River at Priest Rapids	C-400	Left Shore	9-24-51		58 ± 25							30[W] ± 95	26 ± 60		93 ± 15	
			10-22-51										15 ± 33			
													30 ± 30			
			12-3-51												18 ± 18	
													-2 ± 40		61 ± 30	
															37 ± 41	
			1-28-62	116 ± 190				49 ± 14								
			2-11-62										49 ± 49			
		Comp.	2-25-62	29 ± 10									61 ± 37			
				183 ± 120												
		L-Shore											17 ± 27			
													79 ± 47			
		Comp.	3-10-62	245 ± 110												
				528 ± 140												
			3-24-62	65 ± 160												
				158 ± 130												
			4-16-62	171 ± 98												
				179 ± 110												
			4-28-62	322 ± 109												
				298 ± 74												
			5-12-62	448 ± 130												
				112 ± 190												
			6-2-62	6 ± 90												
				44 ± 130												
		L-Shore	6-2-62					35 ± 22								
								31 ± 25								
		Comp.	7-2-62	334 ± 150												
				362 ± 180												
			8-1-62	133 ± 250												
				577 ± 250												
			9-15-62	244 ± 290												
				382 ± 270												
		L-Shore											46 ± 48		36 ± 9	
													53 ± 33		13 ± 16	
													62 ± 50		27 ± 49	
		Comp.	10-1-62	228 ± 110												
				590 ± 160												
		L-Shore								11 ± 21			53 ± 64	131 ± 170		
										13 ± 28			18 ± 69			
		Comp.	11-10-62	400 ± 490												
				3800 ± 340												
		L-Shore						163 ± 28			58 ± 26		47 ± 66	32 ± 44	8 ± 9	
								372 ± 41						25 ± 44	60 ± 17	
		Comp.	12-10-62	1040 ± 360												
				1150 ± 420												
		L-Shore								102 ± 33	50 ± 30		14 ± 64	21 ± 44	104 ± 100	
										59 ± 32	41 ± 27			52 ± 50	24 ± 19	
		Comp.	1-19-63	154 ± 230												
				358 ± 260												
				196 ± 700												
		L-Shore			103 ± 67						31 ± 22			53 ± 53	45 ± 24	
					86 ± 35						8 ± 10				-25 ± 60	
		L-Shore	2-25-63	305 ± 220				108 ± 23							12 ± 28	
				366 ± 250				122 ± 20							20 ± 14	
		L-Shore	3-17-63	414 ± 320				242 ± 47								
				388 ± 340				186 ± 48								
Columbia River above Hanford Works	C-385	L-Shore	10-22-61										-19 ± 28		4 ± 8	
													41 ± 33			
			11-6-61										13 ± 21		21 ± 9	
															22 ± 12	
			12-3-61												16 ± 13	
															21 ± 21	
															16 ± 13	

(1) Stonefly nymphs
(2) Mayfly nymphs
(3) Oligochaetes
(4) Dragonfly nymphs
(5) Filamentous bacteria (Sphaerotilus sp.)
(6) Clams (Sphaeriidae)
(7) Midgefly larvae
(8) Scuds (Corophium)
(9) Blackfly larvae

* Facing Upstream

Table B-7 RADIOACTIVITY OF AQUATIC ORGANISMS (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY in 10^{-7} uc/gram												
				PLANTS						ANIMALS						
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample	PLANKTON	FILAMENTOUS ALGAE Cladophora sp	Stigeoclonium sp	Spirogyra sp	Ulothrix sp	Miscellaneous	SPONGE - PORIFERA	AQUATIC INSECTS Caddisfly larvae (Trichoptera)	Other insect larvae (See footnotes)	MOLLUSKS Snails-whole (s-soft parts only)	Limpets-whole (s-soft parts only)	CRUSTACEANS Crayfish (Astacus trowbridgii)	MISCELLANEOUS (See footnotes)
Columbia River above Hanford Works (cont'd)	C-385	L-Shore	1-28-62										27 ± 42			
													1 ± 19			
			2-11-62										48 ± 95			
													15 ± 70			
		Comp.	3-25-62	272 ± 120												
				174 ± 100												
			3-10-62	251 ± 92												
				124 ± 95												
			3-24-62	105 ± 77												
				556 ± 120												
			4-28-62	368 ± 120												
				304 ± 120												
			5-12-62	331 ± 120												
				263 ± 150												
			8-11-62	392 ± 240												
				502 ± 220												
			11-10-62	2700 ± 400												
				2840 ± 370												
			12-15-62	873 ± 340												
				880 ± 330												
			3-17-63	684 ± 280												
				635 ± 260												
Columbia River above Coyote Rapids	C-383	L-Shore	9-25-61		2,060					208	434		266		143	
			10-22-61										1,780		187	
															203	
			11-6-61	53,500						740	1,580		408		171	
													202			
			12-3-61	45,300									500	1,190	685	
													392		764	
															760	
			1-29-62	44,100												
			2-11-62	278,000												
				262,000												
			2-25-62	181,000	73,500								910		1,230	
				128,000									(e) 3,160			
			3-10-62	103,000				38,200					815		4,230	2,140 (9)
													(e) 2,180		1,430	
			3-24-62	61,800											82	
		Comp.	4-16-62	1,370												
				1,570												
		L-Shore	4-28-62	53,500											376	
				41,500												
		Comp.	5-12-62	1,890												
				4,690												
		L-Shore	6-2-62	1,530				134							151	
				1,930				152							252	
		Comp.	7-18-62	11,600												
				15,400												
		Comp.	8-11-62	21,800												
				19,200												
		L-Shore	9-15-62	6,350				1,630		411	5,800		2,150		896	
				6,720				1,520			5,380		2,970		1,500	
													2,930			
			10-1-62	81,000	4,180					1,970	7,120		3,040	3,230		
				104,000	2,980					1,840	3,370		2,520	3,040		
			11-10-62	31,200				41,200		2,840	6,[illegible]		2,280	2,830	2,590	
				16,600				11,100		2,370	7,080			1,960	1,630	
															3,900	
			12-10-62			32,000				5,670	17,300		5,200	8,400	2,310	
						55,000				5,710	16,700		5,020	7,440		
		Comp.	12-15-62	9,250												
				6,960												
		L-Shore	1-15-63	49,500							9,490			3,350	862	
				49,500							9,800			4,560	1,820	
		L-Shore	2-15-63	34,100				1,250					156			
				38,100				1,680					107			
			3-17-63	60,000				1,390								
				99,500				1,310								

(1) Stonefly nymphs
(2) Mayfly nymphs
(3) Chironomidae
(4) Dragonfly nymphs
(5) Filamentous bacteria (Sphaerotilus sp.)
(6) Clams (Sphaeriidae)
(7) Midgefly larvae
(8) Scuds (Corophium)
(9) Blackfly larvae

* Facing Upstream

Table B-7 RADIOACTIVITY OF AQUATIC ORGANISMS (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY in 10^{-7} μc/gram													
				PLANTS						ANIMALS							
Sampling Range	Mileage Index Number	Location of Sample *	Date of Sample	PLANKTON	FILAMENTOUS ALGAE Cladophora sp	Stigeoclonium sp	Spirogyra sp	Ulothrix sp	Miscellaneous	SPONGE - PORIFERA	AQUATIC INSECTS Caddisfly larvae (Trichoptera)	Other insect larvae (See footnotes)	MOLLUSKS Snails-whole (s-soft parts only)	Limpets-whole (s-soft parts only)	CRUSTACEANS Crayfish (Astacus trowbridgii)	MISCELLANEOUS (See footnotes)
Columbia River at Hanford Ferry Crossing	C-362	L-Shore	9-24-61		29,800											
			10-15-61										7,800		22,800	
			10-29-61										14,700			
			1-30-62	198,000									10,500			
			2-6-62	103,000									7,250			
			2-11-62	108,000									352			
				343,000												
				267,000												
				510,000												
				550,000												
				908,000												
			2-19-62	114,000											202	
				170,000												
				98,500												
				146,000												
				148,000												
				150,000												
			3-3-62	268,000												
				218,000												
			3-6-62	164,000												
				145,000												
			3-17-62	242,000												
				146,000												
				205,000												
				233,000												
				210,000												
				262,000												
			4-7-62	117,000												
				118,000												
			4-22-62	230,000												
				238,000												
			5-6-62	22,600												
				22,200												
			6-16-62	18,700				33,400								
				23,400												
			7-8-62	112,000				19,600								
				185,000												
			7-22-62	193,000												
				185,000												
				203,000												
			7-30-62	259,000												
				238,000												
				215,000												
			8-4-62	224,000			14,100									
				212,000			15,300									
							27,800									
			9-9-62	288,000	30,700			51,200		6,000	48,500		18,000		2,830	
				296,000	30,300			37,600		9,100	61,500		20,200			
													23,600			
			10-7-62	516,000	45,500	117,000				23,900	77,800		18,200	22,200	7,850	
				560,000	50,000	135,000				40,000			22,200	25,000		
			11-3-62	668,000	47,200						102,000		22,200	24,200		
				612,000	67,000						97,000			32,500		
			12-10-62	177,000	27,800	47,500					47,500			11,100		
				183,000	43,200	70,000					47,100			15,600		
			1-8-63	680,000	79,500						35,000			10,400		
				768,000	86,700						38,100			12,400		
			2-4-63					44,000								
								53,100								
			3-2-63	406,000				94,200								
								95,500								
			3-16-63	274,000	40,400	66,600										
				218,000	39,500	77,700										
				236,000												
				314,000												
Columbia River at Richland, Wash.	C-339	L-Shore	10-10-61													
			12-11-61	248,000									1,540		5,000	
			1-29-62	236,000												
		Slough											84			
													161			
		L-Shore	2-4-62	107,000			42									
		Slough					78									

(1) Stonefly nymphs
(2) Mayfly nymphs
(3) Oligiochaetes
(4) Dragonfly nymphs
(5) Filamentous bacteria (Sphaerotilus sp.)
(6) Clams (Sphaeriidae)
(7) Midgefly larvae
(8) Scuds (Corophium)
(9) Blackfly larvae

* Facing Upstream

Table B-7 RADIOACTIVITY OF AQUATIC ORGANISMS (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY in 10^{-7} μc/gram													
				PLANTS							ANIMALS						
Sampling Range	Mileage Index Number	Location of Samples	Date of Sample	PLANKTON	FILAMENTOUS ALGAE Cladophora sp	Stigeoclonium sp	Spirogyra sp	Ulothrix sp	Miscellaneous	SPONGE - PORIFERA	AQUATIC INSECTS Caddisfly larvae (Trichoptera)	Other insect larvae (See footnotes)	MOLLUSKS Snails-whole (s-soft parts only)	Limpets-whole (s-soft parts only)	CRUSTACEANS Crayfish (Astacus trowbridgii)	MISCELLANEOUS (See footnotes)
Columbia River at Richland, Wash. (cont'd)	C-339	L-Shore Slough	2-18-52	199,000			38								16	
							126									
							43									
		L-Shore	3-3-52	179,000												
				97,600												
			3-11-52	139,000												
				136,000												
				113,000												
				128,000												
			3-18-52	151,000												
				105,000												
				120,000												
				118,000												
				110,000												
				122,000												
			3-24-52	111,000												
				192,000												
				99,000												
			4-7-52	76,700												
				78,100												
			4-23-52	105,000												
				77,500											1,120	
			5-8-52	17,500												
				17,400											446	
			6-17-52	22,000												
				22,600									380			
			7-8-52	18,000			690		2,720							
							854									
			8-4-52	85,200			1,060								1,520	
				86,200			1,130									
							12,400									
			9-9-52	162,000	3,440		1,760				17,700		7,700		4,550	
				170,000	2,440		1,410				16,000		7,380			
			10-6-52	210,000	8,950		12,000			15,500	24,800		5,940	4,950		
				212,800	8,370		10,900			19,400	44,200		5,950			
											13,700					
											12,300					
			11-4-52	264,000			5,380				37,100		5,460			
				300,000			3,710				31,000		9,520			
			12-19-52	342,000							17,400		980	7,250		
				410,000							17,200		1,850	6,470		
													4,540	7,110		
			1-6-53						63,000		24,200		1,530	7,550		
									59,000		27,600		1,670	7,020		
			2-10-53		16,800											
					18,700											
					19,200											
					18,000											
Columbia River above Kennewick, Wash.	C-330	L-Shore	9-26-51								7,100					
			10-11-51				294						2,960	513		
			10-30-51				1,950						2,880	6,780		
			3-3-52	118,000												
				124,000												
			3-17-52	73,000												
				185,000												
			4-8-52	44,500												
				62,300												
			4-21-52	76,700										340		
				72,500												
			5-5-52	20,000												
				12,400												
			6-9-52	11,600				2,760								
				11,800												
			8-5-52	72,400												
				105,000												
			9-8-52	96,700							12,000	2,080[8]	3,900		6,310	
				115,000								2,550[8]			4,050	
												4,600[8]				

(1) Stonefly nymphs
(2) Mayfly nymphs
(3) Oligiochaetes
(4) Dragonfly nymphs
(5) Filamentous bacteria (Sphaerotilus sp.)
(6) Clams (Sphaeriidae)
(7) Midgefly larvae
(8) Scuds (Corophium)
(9) Blackfly larvae

* Facing Upstream

Table B-7 RADIOACTIVITY OF AQUATIC ORGANISMS (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY in 10^{-7} μc/gram												
				PLANTS						ANIMALS						
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample	PLANKTON	FILAMENTOUS ALGAE Cladophora sp	Stigeoclonium sp	Spirogyra sp	Ulothrix sp	Miscellaneous	SPONGE - PORIFERA	AQUATIC INSECTS Caddisfly larvae (Trichoptera)	Other insect larvae (See footnotes)	MOLLUSKS Snails-whole (s-soft parts only)	Limpets-whole (s-soft parts only)	CRUSTACEANS Crayfish (Astacus trowbridgii)	MISCELLANEOUS (See footnotes)
Columbia River below Pasco, Wash.	C-326	L-Shore	10-1-51						19,000		7,270		3,670		1,660	9,768[5]
			10-11-51		817								312		622	
					916								330		306	
			10-31-51												14,200	
			1-29-52	178,000				16,500								
			2-18-52	63,100					7,130		5,100				755	
				100,000					8,130							
									8,670							
			3-3-52	80,800												
				54,000												
			3-17-52	96,600												
				73,300												
			4-8-52	60,700											456	
				51,800												
			4-21-52	59,900											446	
				65,200												
			5-5-52	23,700												
				22,800												
			6-9-52	10,200												
				9,560												
			7-15-52	75,800												
				43,600												
			8-5-52	92,000												
				90,500												
			9-8-52	123,000	10,200						11,000				4,250	
				123,000	5,650						26,200				9,660	
			10-8-52	208,000	4,740	24,500				9,800	37,000		9,770	9,550	1,640	
				205,000	4,660	23,200				11,100	41,200			12,500	890	
															1,370	
			11-4-52	131,000		35,200				20,600	41,600		11,800	11,100	14,800	
				141,000		37,300				20,800	34,400		8,550	11,100		
			12-17-52	124,000							14,400		1,190	6,950		
				130,000							15,500		2,500	7,400		
Columbia River above the Walla Walla River	C-316	L-Shore	10-1-51								10,700		785		3,740	
		R-Shore	11-14-51												264	
			11-28-51	10,900											118	
			12-12-51	2,580												
		L-Shore	2-6-52	34,100												
		R-Shore	2-20-52	1,020							56			47	38	
				1,170							80		(a)	30	55	
															44	
			3-3-52	43,500												
				57,800												
			3-19-52	48,000												
				52,000												
			4-23-52	23,800												
				2[illegible],000												
			5-7-52	8,240												
				13,100												
			8-13-52	32,800												
				26,800												
			11-17-52	78,200							780	51[10]	95	119	206	
				97,000							514		206	176	108	
Columbia River at Juniper Canyon	C-306	R-Shore	10-16-51							12,400			2,410			
													1,790			
		L-Shore	11-16-51				2,640		1,350				2,715		2,590	
									1,475							
			11-28-51										818		3,710	
		R-Shore	12-12-51	13,800											1,490	
		L-Shore	1-23-52	56,200												
		R-Shore	2-6-52	4,800											593	
															320	
			3-5-52	21,000												
				17,100												
			3-19-52	24,000												
				24,500												
			4-23-52	25,000											225	
				21,000												

(1) Stonefly nymphs
(2) Mayfly nymphs
(3) Oligiochaetes
(4) Dragonfly nymphs
(5) Filamentous bacteria (Sphaerotilus sp.)
(6) Clams (Sphaeriidae)
(7) Midgefly larvae
(8) Scuds (Corophium)
(9) Blackfly larvae

* Facing Upstream

Table B-7 RADIOACTIVITY OF AQUATIC ORGANISMS (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY in 10^{-7} μc/gram												
				PLANTS						ANIMALS						
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample	PLANKTON	FILAMENTOUS ALGAE Cladophora sp	Stigeoclonium sp	Spirogyra sp	Ulothrix sp	Miscellaneous	SPONGE - PORIFERA	AQUATIC INSECTS Caddisfly larvae (Trichoptera)	Other insect larvae (See footnotes)	MOLLUSKS Snails-whole (s-soft parts only)	Limpets-whole (s-soft parts only)	CRUSTACEANS Crayfish (Astacus trowbridgii)	MISCELLANEOUS (See footnotes)
Columbia River at Juniper Canyon (cont'd)	C-305	Comp.	5-7-52	8,675												
				7,620												
			6-18-52	8,025												
				12,200												
		L-Shore	7-9-52	15,400				2,880								
				13,000				3,080								
		Comp.	8-13-52	37,000												
				34,800												
		R-Shore	9-10-52						5,340							
									5,550							
			10-29-52	63,200	10,200						20,800		7,080	3,910	3,170	1,455 (6)
				56,600	10,100						22,600		6,400	12,100		
			11-17-52	68,200					11,900		18,600		6,460	6,875	880	
				63,500					14,400		16,900		4,950	2,490	3,010	
		L-Shore	12-8-52								3,670		1,250		1,620	
											4,125		1,085			
		Comp.	12-17-52	45,500												
				51,800												
Columbia River above McNary Dam	C-297	L-Shore	10-2-51				2,080				34,200		4,950	3,880	1,590	
			10-18-51				548						1,260			
			-7-51				1,270		4,350				1,300		791	
							1,205						1,110		1,995	
															1,670	
			11-20-51				815						1,160		3,130	
							880						692		1,750	
			1-10-52												279	
			2-13-52	7,000							2,580	5,300 (7)	-9	(a) 1,195	393	
				6,850							2,780		284	(a) 1,280	79	
											3,000		(a) 1,330		356	
													(a) 344			
			2-27-52	19,800							1,910		69	614	319	
				17,400							2,390		(a) 729	(a) 615	15	
											2,290		(a) 1,070		306	
													(a) 57			
			3-12-52	14,200							1,830	5,490 (7)	353	572	463	
				16,200							1,625	5,470 (7)	787	(a) 890	234	
													(a) 1,060		229	
													(a) 582			
			3-26-52													
		Comp.	4-23-52	5,650											274	
				7,600												
			6-18-52	6,400					405							
				6,220												
		L-Shore	7-9-52	6,700				2,820								
				6,750												
			8-6-52	19,000					1,180							
				13,900					1,430							
			9-10-52	26,600					1,785	4,800	10,700		1,850	2,820	1,840	
				26,600					1,655	4,900	13,950		2,020			
			10-15-52	54,000					8,350	8,400	12,800		3,400	3,240		
				64,600					7,100	10,000	11,800		2,220	3,160		
			11-5-52	65,000						10,600	17,850		2,930	4,500		
				63,500						10,200	13,600			4,550		
			12-17-52	37,300							6,770		1,010	4,600		
				38,200									982	4,690		
			1-7-53	42,100					3,200		7,110		1,680	2,700		
				83,500					7,250		6,620			3,190		
Columbia River at Paterson, Wash.	C-278	L-Shore	10-2-51								29,400		4,140			
			10-18-51										2,260			
													2,900			
			11-7-51							4,900			2,280			
			2-13-52	1,330							2,760		260	(a) 1,040		
				1,980									(a) 210			
													350			
			2-27-52	11,700							1,560		(a) -8			
				15,100							2,560		(a) 540			
													-38			
													(a) 1,230			

(1) Stonefly nymphs
(2) Mayfly nymphs
(3) Oligochaetes
(4) Dragonfly nymphs
(5) Filamentous bacteria (Sphaerotilus sp.)
(6) Clams (Sphaeridae)
(7) Midgefly larvae
(8) Snails (Ceropkium)
(9) Blackfly larvae

* Facing Upstream

Table B-7 RADIOACTIVITY OF AQUATIC ORGANISMS (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY in 10^{-7} μc/gram												
				PLANTS						ANIMALS						
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample	PLANKTON	FILAMENTOUS ALGAE Cladophora sp	Stigeoclonium sp	Spirogyra sp	Ulothrix sp	Miscellaneous	SPONGE - PORIFERA	AQUATIC INSECTS Caddisfly larvae (Trichoptera)	Other insect larvae (See footnotes)	MOLLUSKS Snails - whole (s - soft parts only)	Limpets - whole (s - soft parts only)	CRUSTACEANS Crayfish (Astacus trowbridgii)	MISCELLANEOUS (See footnotes)
Columbia River at Paterson, Wash. (cont'd)	C-278	L-Shore	1-26-52													
			4-23-52	5,840											92	
				6,920												
			6-18-52	6,200		3,580		1,510								
				9,400		3,580		1,440								
			7-9-52	6,600				765								
				6,470				535								
			8-6-52	20,800												
				18,100												
			9-10-52	34,800	1,590						13,500		2,520	1,740	9,400	(a) 4,700 (5)
				36,500	1,610								3,930	1,490		16,900 (8)
			10-15-52	70,300	3,380						15,700		4,640	2,620		
				50,500	3,180								2,970	3,670		
			11-5-52	62,500	5,750			3,840			26,800		850	5,100		
				48,600	6,220			5,690					2,540	5,300		
			12-17-52	36,400	15,800											
				37,100	14,000											
			2-11-53					5,870								
								5,970								
			3-4-53					18,800								
Columbia River below Corbett, Ore.	C-125	R-Shore	11-12-52	10,400					420							
				9,000												
			3-31-53	10,000												
				10,000												
Columbia River below Astoria, Ore.	C-13	R-Shore	11-10-52	6,200					230							
				6,000					190							
			3-30-53	14,000					800							
				23,000					1,100							
									1,100							
TRIBUTARIES																
Yakima River at Kiona, Wash.	CY-36	L-Shore	10-18-51					215 ± 70					32 ± 54		9 ± 39	
															-160 ± 80	
Yakima River at Enterprise, Wash.	CY-30	R-Shore	10-18-51								-73 ± 48				-50 ± 17	
			1-30-52	145 ± 92											-78 ± 49	
			3-26-52													
			4-30-52												20 ± 9	
															7 ± 24	
			6-23-52	500 ± 140											39 ± 46	
				230 ± 126					80 ± 39			15 (9) ± 29			13 ± 11	
			9-9-52	147 ± 120					186 ± 62			43 (9) ± 34			15 ± 18	
				215 ± 118											19 ± 10	
			11-5-52	1200 ± 306											65 ± 23	
Yakima River at Richland Highway Bridge	CY-339	L-Shore	10-18-51								-32 ± 60	89 (9) ± 85			74 ± 40	
			11-20-51												307 ± 67	
															46 ± 11	
															0 ± 31	
			2-22-52	0 ± 150												
				128 ± 139												
			3-12-52	-110 ± 106							-15 ± 25	-26 (7) ± 37				
				24 ± 74								-122 ± 42				
												-47 (9) ± 31				
			5-7-52													
															14 ± 20	
			7-23-52	65 ± 162	34 ± 15										20 ± 19	
				79 ± 165	42 ± 15											
			10-29-52	1190 ± 350												
				1200 ± 380												

(1) Stonefly nymphs
(2) Mayfly nymphs
(3) Oligtochaetes
(4) Dragonfly nymphs
(5) Filamentous bacteria (Sphaerotilus sp.)
(6) Clams (Sphaeriidae)
(7) Midgefly larvae
(8) Scuds (Corophium)
(9) Blackfly larvae

* Facing Upstream

Table B-7 RADIOACTIVITY OF AQUATIC ORGANISMS (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY in 10^{-7} μc/gram												
				PLANTS						ANIMALS						
Sampling Range	Mileage Index Number	Location of Sample*	Date of Sample	PLANKTON	FILAMENTOUS ALGAE Cladophora sp	Stigeoclonium sp	Spirogyra sp	Ulothrix sp	Miscellaneous	SPONGE-PORIFERA	AQUATIC INSECTS Caddisfly larvae (Trichoptera)	Other insect larvae (See footnotes)	MOLLUSKS Snails-whole (s=soft parts only)	Limpets-whole (s=soft parts only)	CRUSTACEANS Crayfish (Astacus trowbridgii)	MISCELLANEOUS (See footnotes)
Snake River at Page, Wash.	CS-342	Lefbore	11-20-51	710 ± 175												
			3-20-52	120 ± 107												
				170 ± 120											6 ± 12	
Snake River near the mouth	CS-325	Lefbore	10-31-51													
			1-23-52	370 ± 160									2 ± 15			
			4-30-52													
			6-21-52	210 ± 190											20 ± 13	
				105 ± 220											14 ± 12	
			7-23-52	85 ± 110											35 ± 14	
				160 ± 127												
			8-5-52	1260 ± 250												
				1040 ± 240												
			10-8-52	1090 ± 300												
				1740 ± 450							685 ± 61				125 ± 11	
			11-4-52	2860 ± 720												
				3070 ± 630												
Walla Walla River at old Highway Crossing	CWw-322		10-2-51													
			3-5-52								34 ± 7				508 ± 51	
			3-19-52								34 ± 23				15 ± 15	
											30 ± 23					
			4-20-52								12 ± 24					
			6-25-52	120 ± 130	82 ± 52										13 ± 10	
				19 ± 120	42 ± 51										2 ± 15	
															26 ± 13	
			7-23-52	264 ± 150	18 ± 13						-3 ± 15	-9[illegible] ± 7			10 ± 9	
					18 ± 12						43 ± 18					
			8-13-52	81 ± 162	26 ± 19											
					26 ± 21											
			10-29-52	413 ± 174												
				274 ± 228												
			11-17-52	1030 ± 252				225 ± 50			58 ± 29				15 ± 9	
								162 ± 39			87 ± 33				30 ± 17	
															49 ± 25	

(1) Stonefly nymphs
(2) Mayfly nymphs
(3) Oligiochaetes
(4) Dragonfly nymphs
(5) Filamentous bacteria (Sphaerotilus sp.)
(6) Clams (Sphaeridae)
(7) Midgefly larvae
(8) Scuds (Corophium)
(9) Blackfly larvae

* Facing Upstream

Table B-8 RADIOACTIVITY OF JUVENILE FISH (ENTIRE)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY as 10^{-7} μc/gm.																	
							CYPRINIDAE - Carp and Minnow Family							CENTRARCHIDAE - Bass and Sunfish Family					COTTIDAE Sculpin Family	
Sampling Range	Mileage Index Number	Location of Sample*	Date of Sample	SALMONIDAE - Salmon and Trout Family	Oncorhyncus tshawytscha (Chinook salmon)	CATOSTOMIDAE - Sucker Family	Catostomus sp (Suckers)	Cyprinus carpio (Carp)	Acrocheilus alutaceus (Chiselmouth)	Mylocheilus caurinus (Columbia River chub)	Rhinichthys sp (Dace)	Ptychocheilus oregonensis (Squawfish)	Richardsonius balteatus (Columbia River shiner)	GASTEROSTIDAE - Stickleback Family	Gasterosteus aculeatus (Three-spined stickleback)	Micropterus dolomieu (Smallmouth bass)	Micropterus salmoides (Largemouth bass)	Lepomis sp (Sunfish)	Pomoxis sp (Crappie)	Cottus beldingi (Smoothe sculpin)	Cottus sp (Prickly sculpins)
Columbia River above Trinidad, Wash.	C-445	Right Shore	1-12-53																		9 ± 11
																					2 ± 15
																					12 ± 16
																					8 ± 16
																					8 ± 8
																					-3 ± 17
Columbia River at Priest Rapids	C-400	Left Shore	9-24-51			-26 ± 24															
						16 ± 30															54 ± 36
			10-22-51			37 ± 62					24 ± 26	38 ± 46	48 ± 39								
											14 ± 34	81 ± 29	55 ± 39								
			11-6-51										36 ± 21								
													67 ± 24								
													55 ± 28								
			11-19-51			29 ± 16					-10 ± 23	22 ± 13	20 ± 16								
						30 ± 33					9 ± 12	95 ± 26	34 ± 18								59 ± 31
												35 ± 21	16 ± 13								
			12-3-51																	11 ± 7	9 ± 7
																				-18 ± 14	
			2-11-52			-1 ± 19						-19 ± 26	33 ± 45								
						-13 ± 15						-11 ± 30	60 ± 36								
													-13 ± 35								
			2-29-52			21 ± 25				4 ± 17	-54 ± 51	11 ± 20	2 ± 35	-13 ± 62							
						10 ± 30						18 ± 32									10 ± 32
						11 ± 21						-5 ± 25									
			4-16-52	23 ± 17					11 ± 15			27 ± 28	22 ± 18	2 ± 38							
				40 ± 23					-3 ± 17			17 ± 19	30 ± 16	-2 ± 38							
												40 ± 14									
			4-28-52	-11 ± 12		-50 ± 30					-4 ± 11	-20 ± 17									
				20 ± 12							2 ± 20	4 ± 38									
				5 ± 14								-13 ± 26									
				-13 ± 12																	
				-9 ± 14																	
			5-12-52			16 ± 8			-43 ± 39	-10 ± 10	29 ± 25	11 ± 18	30 ± 13								
						-34 ± 16				15 ± 14		19 ± 16	14 ± 15								
										-13 ± 10		-9 ± 19	11 ± 17								
			6-2-52			16 ± 10				30 ± 11	82 ± 18	83 ± 16	39 ± 14								
						18 ± 14					22 ± 13	38 ± 20	67 ± 22								29 ± 17
						18 ± 12					87 ± 17		21 ± 12								75 ± 18
			7-28-52									36 ± 17	42 ± 11								30 ± 16
												10 ± 13	39 ± 12								
												19 ± 10	43 ± 12								
			8-11-52									105 ± 10	88 ± 12								
												12 ± 14	60 ± 12								
												50 ± 19	61 ± 13								
			9-15-52			27 ± 16				58 ± 31		63 ± 6	32 ± 7								21 ± 6
						16 ± 18						60 ± 7	40 ± 11								
												59 ± 18	90 ± 23								
			10-13-52			26 ± 9				79 ± 16		31 ± 15	90 ± 20								
						15 ± 12				66 ± 17		41 ± 22	172 ± 30								
						5 ± 23				52 ± 19			129 ± 25								
			11-10-52			29 ± 12				99 ± 13		115 ± 34	73 ± 18								56 ± 11
						58 ± 16				177 ± 19			470 ± 24								
						140 ± 16							236 ± 27								
			12-10-52			18 ± 18						19 ± 16	17 ± 17								
						26 ± 12						19 ± 14	31 ± 21								2 ± 23
						38 ± 20						12 ± 19	66 ± 41								31 ± 15
			1-19-53			20 ± 7						17 ± 8	28 ± 23								-5 ± 18
						8 ± 9						14 ± 16	-10 ± 15								13 ± 7
						28 ± 10						10 ± 14	-3 ± 14								
						15 ± 12						6 ± 15	15 ± 15								
												42 ± 21									
			2-25-53			21 ± 25						0 ± 25	23 ± 53								
						11 ± 29						31 ± 18	110 ± 37								
													54 ± 37								
			3-17-53	31 ± 16									18 ± 35								
				3 ± 13																	
				-5 ± 18																	
Columbia River above Hanford Works	C-385		10-4-51			39 ± 21			365 ± 84		101 ± 24	603 ± 39	402 ± 83								
						25 ± 23			444 ± 98		182 ± 7	152 ± 40	240 ± 52								
													92 ± 25								

* Facing Upstream

Table B-8 RADIOACTIVITY OF JUVENILE FISH (ENTIRE) (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY as 10^{-7} μc/gm.																	
							CYPRINIDAE - Carp and Minnow Family							CENTRARCHIDAE - Bass and Sunfish Family				COTTIDAE Sculpin Family	
Sampling Range	Mileage Index Number	Location of Sample*	Date of Sample	SALMONIDAE - Salmon and Trout Family Oncorhyncus tshawytscha (Chinook salmon)	CATOSTOMIDAE - Sucker Family Catostomus sp (Suckers)	Cyprinus carpio (Carp)	Acrocheilus alutaceus (Chiselmouth)	Mylocheilus caurinus (Columbia River chub)	Rhinichthys sp (Dace)	Ptychocheilus oregonensis (Squawfish)	Richardsonius balteatus (Columbia River shiner)	GASTEROSTIDAE - Stickleback Family Gasterosteus aculeatus (Three-spined stickleback)	Micropterus dolomieu (Smallmouth bass)	Micropterus salmoides (Largemouth bass)	Lepomis sp (Sunfish)	Pomoxis sp (Crappie)	Cottus beldingi (Smoothe sculpin)	Cottus sp (Prickly sculpins)
Columbia River above Hanford Works (cont'd)	C-385	Left Shore	6-2-52		26 ± 10			11 ± 11	30 ± 34	21 ± 9	24 ± 10								
					6 ± 19			21 ± 15		24 ± 12	40 ± 14								
					9 ± 11			15 ± 12		545 ± 32	20 ± 12								
			8-11-52		30 ± 11			161 ± 18		82 ± 10		-5 ± 25							
					25 ± 11			285 ± 28		121 ± 19									
					16 ± 12			332 ± 30		88 ± 16									
Columbia River above Coyote Rapids	C-383		9-25-51								607								
											700								
			10-4-51		695		1,130		2,810	3,600	2,440								
					697		3,940				1,990								
											2,940								
			10-22-51				554		7,100	462	682	4,140							
									1,850	510	463								
										11,700	368								
			12-3-51							207	386	957							39
			1-28-52		79			138		63	100	432							27
											138								
											154								
											132								
											137								
											120								
			2-11-52		248		755			131	105	381							
										98	334								
										189	230								
			2-25-52		625				1,420	407	222								
					836					278	605								
										366	324								
			3-10-52							97	1,100	788					148		
											283						167		
											359								
			3-24-52					850		25	263								310
								244		44	130								367
								153		182	160								
			4-16-52		646			140		172	232								
					1,000			180		266	218								
								156		403	216								
			4-28-52	394	640			93		226	215								
					511			485		130	228								350
					722			300		274	385								385
			5-12-52	242					263	197	176								
				344						182	292								425
										296	397								948
			6-2-52		36				515	1,070	118								356
									151	39	264								239
									312	64	655								233
			7-28-52								423								483
											506								
											381								
			8-11 52		2,660					204	1,330	1,620							
										1,390	2,800	2,040							990
										377	1,600								
			9-15-52		2,870				9,500	13,000	3,780								
										64,100	6,070								
										58,600	7,270								
			10-13-52							10,800	3,160								
											4,500								6,460
											5,500								
			11-10-52								1,290								
											2,670								
											1,540								
			12-10-52								1,940								
											3,080								
			1-19-53								3,750								
			2-25-53								2,440	878					3,980		
											675								
											515								
			3-17-53	374	244						369								
				206						74	207								
				160						123	191								
				145							215								

* Facing Upstream

Table B-8 RADIOACTIVITY OF JUVENILE FISH (ENTIRE) (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY as 10^{-7} μc/gm.																
						CYPRINIDAE - Carp and Minnow Family							CENTRARCHIDAE - Bass and Sunfish Family				COTTIDAE Sculpin Family	
Sampling Range	Mileage Index Number	Location of Sample*	Date of Sample	SALMONIDAE - Salmon and Trout Family Oncorhynchus tshawytscha (Chinook salmon)	CATOSTOMIDAE - Sucker Family Catostomus sp (Suckers)	Cyprinus carpio (Carp)	Acrocheilus alutaceus (Chiselmouth)	Mylocheilus caurinus (Columbia River chub)	Rhinichthys sp (Dace)	Ptychocheilus oregonensis (Squawfish)	Richardsonius balteatus (Columbia River shiner)	GASTEROSTIDAE - Stickleback Family Gasterosteus aculeatus (Three-spined stickleback)	Micropterus dolomieu (Smallmouth bass)	Micropterus salmoides (Largemouth bass)	Lepomis sp (Sunfish)	Pomoxis sp (Crappie)	Cottus beldingi (Smoothe sculpin)	Cottus sp (Prickly sculpins)
Columbia River at Hanford Ferry Crossing	C-362	Left Shore	10-8-51		78,000		24,700			16,100	15,900							33,400
					90,500					24,000	18,500							
					34,000					9,860	23,900							
					35,500					50,000	50,400							
					35,400					23,200	[illegible]							
										55,900	75,400							
			10-29-51		22,800		17,900		43,000	9,210	79,500	8,970						
					26,500		24,200			9,540	56,000							
					44,400					11,500	19,700							
											19,300							
											37,200							
			11-19-51								3,300							8,800
											8,000							13,500
											6,980							
			11-27-51				5,230			3,060	7,190							
							7,750			3,260	4,800							
										3,440	4,180							
			12-11-52					4,160		1,610	2,680							
								3,800		1,610	2,380							
								5,200			3,580							
			1-22-52		1,900		3,170			1,110	2,680				516			
										1,320	2,580							
										1,570	2,010							
			1-28-52		397					570	1,590							
										623	1,550							
										1,027	1,700							
			2-5-52		1,360					410	1,470							
										1,240	1,520							
										900	1,450							
			2-18-52					720		270	920							
								716		660	760							
								695		812	1,240							
			3-3-52					710		790	665							
								925		610	752							
								695		490	700							
			3-17-52					870		800	614	1,980						
								1,150		860	830							
								1,080		950	942							
			4-16-52	2,040	4,610			1,660		278	1,130	5,720						862
				2,890	2,570			2,840		1,240	1,410							362
				1,450	4,400			3,060		1,830	2,120							
				3,410							1,660							
				1,830							1,890							
											1,790							
			4-22-52	1,860	5,660			2,580	2,270	1,300	1,620	5,110						1,060
				1,600				4,340		1,600	1,470							616
				1,670				3,900		1,500	2,500							
				860							1,050							
				1,970							1,700							
											1,530							
			4-29-52		3,090					968								
					2,690					2,650								
					3,210					1,700								
			5-6-52	770	6,900				4,190	3,590	2,360							2,510
				2,930							3,270							6,920
				1,680							2,680							
				4,600														
			5-26-52		2,060			1,170		382	1,270							
					1,100			890		665	1,120							
					1,080			2,100		940	1,130							
			6-16-52		11,000		8,800			1,870	8,950	18,000	4,800					5,080
					8,520					9,020	9,900							3,890
					7,550					10,300	10,400							5,040
			7-8-52		16,900				17,500	4,440	6,530							
									13,900	6,420	12,300							
										10,500								
			8-4-52		31,600		11,000			7,550	39,100							
					22,400					12,400	19,000							
					10,400					7,830	9,700							
			9-9-52		16,800		21,000	23,000		11,800	27,900	18,000						
							17,300	26,900		4,840	14,700	18,200						
								28,000		21,100		29,000						
			10-7-52		37,500		38,400	45,500	27,700	11,900	20,000						11,800	
					26,800				23,500	20,900	57,300						21,800	
					139,000				30,000	41,800	67,800							
					79,000													
			11-3-52		34,900		37,300	14,900	43,000	7,800	16,700						26,900	
					76,800			18,000	40,600	11,900	29,100						23,300	
					11,100			17,900		16,600	31,800							

* Facing Upstream

Table B-8 RADIOACTIVITY OF JUVENILE FISH (ENTIRE) (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY as 10^{-7} uc/gm.																
				SALMONIDAE - Salmon and Trout Family		CATOSTOMIDAE - Sucker Family	CYPRINIDAE - Carp and Minnow Family						GASTEROSTIDAE - Stickleback Family	CENTRARCHIDAE - Bass and Sunfish Family				COTTIDAE Sculpin Family	
Sampling Range	Mileage Index Number	Location of Sample*	Date of Sample	Oncorhynchus tshawytscha (Chinook salmon)	Catostomus sp (Suckers)	Cyprinus carpio (Carp)	Acrocheilus alutaceus (Chiselmouth)	Mylocheilus caurinus (Columbia River chub)	Rhinichthys sp (Dace)	Ptychocheilus oregonensis (Squawfish)	Richardsonius balteatus (Columbia River shiner)	Gasterosteus aculeatus (Three-spined stickleback)	Micropterus dolomieu (Smallmouth bass)	Micropterus salmoides (Largemouth bass)	Lepomis sp (Sunfish)	Pomoxis sp (Crappie)	Cottus beldingii (Smoothe sculpin)	Cottus sp (Prickly sculpins)
Columbia River at Hanford Ferry Crossing (cont'd)	C-362	Left Shore	2-3-52		13,900			16,300		7,100	11,900							
								11,700		10,800	10,700							
								13,100		8,930	13,700							
			1-5-53					6,470		4,010	6,280	8,340						
											6,470	5,960						
			2-10-53					2,250		436	1,100							
								2,670		2,870	4,160							
								2,360			3,770							
			3-16-53							2,270	2,950							
											2,890							
											2,160							
			3-25-53	8,540							5,900							
				7,930							4,540							
				5,510														
Columbia River at Richland, Wash	C-339		9-26-51		37,600				28,200	22,900								
			10-10-51		13,100					6,920	9,750		8,360	6,350	6,940	8,340		
					11,800					11,000	10,900				6,550			
											16,800							
			10-30-51							6,250	9,900							
											12,300							
											9,400							
											16,100							
			11-1-51		27,800				25,800									
					26,200				22,000									
					27,800				22,200									
			11-15-51		10,400				22,300	3,520	7,400							
					10,500				7,950	3,950	8,040							
										4,240								
			11-27-51							2,420	2,370							
										3,420	5,680							
											5,580							
			12-11-51				-100			800	19,700						3,210	
		Left Shore	1-22-52		990		204	17		119	71				73			
										107								
										108								
		Left Shore Slough	2-5-52		36		83			48					48			
										50					30			
										46								
			2-18-52							35	62							
										40								
										39								
		Left Shore	3-3-52							587	473							
										540	661							
										410	750							
			3-10-52		577			532		528	742							
										529	783							
										390	398							
			4-7-52		1,520		1,800	1,130		435	1,260				925			
					1,510		888			840	965							
					1,510		1,440			1,130	1,150							
			4-22-52	1,210	1,630			1,780	1,250	1,550	1,190							2,760
				875	2,600					1,350	1,190							2,240
				2,130	2,050					1,100	1,360							
				930														
			5-5-52	2,520	1,840		3,280			121	1,970							
				990	2,000		2,520			1,890	2,400							
				5,000	2,440					2,150	2,180							
				1,640						1,310								
				3,540						1,460								
				3,160						1,660								
				3,990														
			5-12-52	607	2,940					114	1,060							
				1,650						805	1,370							
				1,680						150	1,290							
				1,590							1,310							
				2,[illegible]0							1,360							
			5-19-52							840	993							
										473	958							
										681	1,005							
			6-16-52		7,500				9,620	4,600	5,480	10,800						5,020
									9,250	4,730	5,350	8,940						2,840
									10,100	5,200								1,780

* Facing Upstream

Table B-8 RADIOACTIVITY OF JUVENILE FISH (ENTIRE) (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY as 10^{-7} uc/gm.																	
							CYPRINIDAE - Carp and Minnow Family							CENTRARCHIDAE - Bass and Sunfish Family				COTTIDAE Sculpin Family	
Sampling Range	Mileage Index Number	Location of Sample*	Date of Sample	SALMONIDAE - Salmon and Trout Family: Oncorhyncus tshawytscha (Chinook salmon)	CATOSTOMIDAE - Sucker Family: Catostomus sp (Suckers)	Cyprinus carpio (Carp)	Acrocheilus alutaceus (Chiselmouth)	Mylocheilus caurinus (Columbia River chub)	Rhinichthys sp (Dace)	Ptychocheilus oregonensis (Squawfish)	Richardsonius balteatus (Columbia River shiner)	GASTEROSTIDAE - Stickleback Family: Gasterosteus aculeatus (Three-spined stickleback)	Micropterus dolomieu (Smallmouth bass)	Micropterus salmoides (Largemouth bass)	Lepomis sp (Sunfish)	Pomoxis sp (Crappie)	Cottus beldingii (Smoothe sculpin)	Cottus sp (Prickly sculpins)
Columbia River at Richland, Wash. (cont'd)	C-339	Left Shore	7-8-52							1,800	5,510								
										5,510	8,400								
										3,240	7,530								
			8-4-52		4,650	3,340		8,310		7,490		10,200					2,060	
						4,490		10,200		6,120		13,700					890	
								13,100		7,960		10,400					6,540	
			9-9-52		39,800	5,710			13,700	3,430	14,800	10,700						5,350
					31,800	6,220			843	5,660	24,600	11,400						8,820
									21,800		17,200							3,720
			10-6-52		13,600	15,500	25,300			11,300	36,200	11,200	8,360	9,330	2,030	8,340		8,160
					32,200		21,200			14,000		12,300		14,800	6,630			14,100
					36,200		19,600			29,100		9,480			7,500			16,800
															4,740			
			11-4-52		54,300				28,700	7,680	16,600	6,780					24,500	8,210
					34,700					9,950	17,500	5,970						
					33,800					15,900	24,700	5,770						
			12-3-52							6,020	6,380							5,920
											9,900							6,020
											10,800							
			1-6-53							3,660	648							
											5,020							
											6,380							
			2-10-53		2,260					1,560	4,690							
					1,530					965	4,320							
			3-16-53	3,560						1,340	3,270							
				3,330						1,140	2,180							
Columbia River above Kennewick Wash.	C-330	Left Shore	9-26-51		11,500				28,700	10,100	10,300							
			10-11-51		3,760		5,520			3,930	5,590	4,020			6,600			
										2,450	2,340							
										3,840								
			10-30-51		14,700				14,800	3,400	7,890							4,380
					14,800				14,600	2,600	3,460							
					13,100				10,500	4,950	3,150							
									5,900									
									4,360									
									11,400									
			11-13-51								4,980							
											2,280							
			11-26-51					615		1,290	1,350							
								1,080		478	1,160							
								550		758	1,610							
			12-10-51			145	644	1,030		855	2,180							
							851	678		550	3,420							
							231			424								
			1-21-52		635		864	284		307	720							
										388	892							
										493	426							
			2-4-52				120	103		147	211							
							299			319	348							
										145								
			2-18-52		105		494	176		84	153							
							360	96		104	227							
								278		133	161							
			3-3-52				202	116		111	398							
							416	344		95	394							
							201	254		163	193							
			3-10-52			153	213	188		119	131							
							362	168		166	183							
								166		98	207							
			4-8-52	1,740				942		262	1,110							
								845		401	1,290							
										474	937							
			4-21-52	1,900	263		829			558	1,300				761			421
				1,480							752				782			
				816							811							
				1,200														
				1,180														
			5-5-52	4,650						575	986							2,700
				2,180						685	1,140							1,120
				1,360						1,110	1,320							
			6-9-52		2,800			3,440	3,080	1,900	1,640							
					2,470			3,060		1,670	2,380							
					3,110					2,520	2,220							

* Facing Upstream

Table B-8 RADIOACTIVITY OF JUVENILE FISH (ENTIRE) (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY as 10^{-7} μc/gm.																
							CYPRINIDAE - Carp and Minnow Family							CENTRARCHIDAE - Bass and Sunfish Family				COTTIDAE Sculpin Family	
Sampling Range	Mileage Index Number	Location of Sample *	Date of Sample	SALMONIDAE - Salmon and Trout Family Oncorhyncus tshawytscha (Chinook salmon)	CATOSTOMIDAE - Sucker Family Catostomus sp (Suckers)	Cyprinus carpio (Carp)	Acrocheilus alutaceus (Chiselmouth)	Mylocheilus caurinus (Columbia River chub)	Rhinichthys sp (Dace)	Ptychocheilus oregonensis (Squawfish)	Richardsonius balteatus (Columbia River shiner)	GASTEROSTIDAE - Stickleback Family Gasterosteus aculeatus (Three-spined stickleback)	Micropterus dolomieu (Smallmouth bass)	Micropterus salmoides (Largemouth bass)	Lepomis sp (Sunfish)	Pomoxis sp (Crappie)	Cottus beldingii (Smoothe sculpin)	Cottus sp (Prickly sculpins)
Columbia River above Kennewick, Wash. (cont'd)	C-330	Left Shore	8-5-52		8,280					7,800				6,890				
					11,000					7,190				5,530				
					8,700					6,550								
			9-8-52		31,100	11,200		11,100	12,400	3,900	8,770	10,600	10,000	11,900	14,600			4,080
								20,400	13,700	10,600	8,720		10,200	9,900	8,530			9,240
								21,200	14,500	16,300	10,300			10,700				9,490
			12-8-52							2,510	3,670							3,120
										3,940	4,730							
										2,430	4,210							
Columbia River below Pasco, Wash.	C-326		10-1-51		16,400					8,370	111							
											7,640							
			10-11-51		8,820	1,620	1,090		9,880	1,980	554	810						
					10,900					1,800	1,620							
										4,000	1,840							
											2,140							
			10-31-51		13,800				26,200	6,830	2,320							
					15,200				13,500									
					6,170				17,500									
									11,200									
			11-13-51							1,070	1,540							582
										947	2,780							
										1,740	1,980							
			1-26-51				660			750	1,290							
							462			582	1,100							
										616	1,250							
			12-10-51				460			800	1,100							
										600	710							
											975							
		Left Shore Slough	1-21-52				136			196	356				186			
										310	396							
										155	432							
			2-4-52							141	500				48			
										222	152							
										92	161							
			2-18-52				134			164	276				21			
							115			100	265				34			
										108	98							
			3-3-52				180			115	266							
							161			193	285							
							122			87	213							
			3-17-52				204			129	232				36			
										100	121							
										35	224							
		Left Shore	4-8-52	1,350			700			118	500							
							448			405	505							
							392			368	814							
			4-17-52	1,310														
				976														
				544														
			4-21-52		1,190		710	474	178	171	600				600			
					477		612			649	580							
					840		664			713	685							
			5-5-52	1,040	1,530		1,680			241	838							390
				1,550	1,650		376			737	1,050							
					1,630		730			834	607							
			5-26-52				304		357	247	1,380							200
							234			212	971							
										295	626							
											730							
											930							
											615							
			6-9-52		3,950		4,430		9,350	2,530								
					5,320				5,700	3,280								
					5,100				4,960	4,800								
			7-15-52				2,270		3,200	594	1,840							1,430
							1,380		2,290	1,370	3,470							
							1,530			1,380	3,180							
			8-5-52						13,600	6,730		15,800						
										8,180								
										6,750								
			9-8-52		35,300		6,870		14,400	4,330			8,470		4,900			
					25,800				10,900	5,300			5,810		2,860			
					23,300				30,400	4,750					6,770			
		Right Shore	10-8-52		41,000	5,660				8,410	15,300	12,800	1,860	5,360	6,070			6,260
					11,700	6,730				5,860		12,700	2,550		5,440			2,220
						5,360				6,520		21,000	2,650		10,100			5,530

* Facing Upstream

Table B-8 RADIOACTIVITY OF JUVENILE FISH (ENTIRE) (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY as 10^{-7} uc/gm.																
				SALMONIDAE - Salmon and Trout Family		CATOSTOMIDAE - Sucker Family	CYPRINIDAE - Carp and Minnow Family						GASTEROSTIDAE - Stickleback Family	CENTRARCHIDAE - Bass and Sunfish Family				COTTIDAE Sculpin Family	
Sampling Range	Mileage Index Number	Location of Sample*	Date of Sample	Oncorhynchus tshawytscha (Chinook salmon)		Catostomus sp (Suckers)	Cyprinus carpio (Carp)	Acrocheilus alutaceus (Chiselmouth)	Mylocheilus caurinus (Columbia River chub)	Rhinichthys sp (Dace)	Ptychocheilus oregonensis (Squawfish)	Richardsonius balteatus (Columbia River shiner)	Gasterosteus aculeatus (Three-spined stickleback)	Micropterus dolomieu (Smallmouth bass)	Micropterus salmoides (Largemouth bass)	Lepomis sp (Sunfish)	Pomoxis sp (Crappie)	Cottus beldingi (Smoothe sculpin)	Cottus sp (Prickly sculpins)
Columbia River below Pasco, Wash. (cont'd)	C-326	Right Shore	11-4-52							27,100	5,030	3,740	13,600			4,130		21,400	
										24,300	6,310	6,210	12,300					24,100	
										19,500	9,800	4,700	22,200						
			3-26-53	3,770				186			822	459							
				3,050				161			660	1,380							
											40	844							
Columbia River above Walla Walla River	C-316	Left Shore	10-1-51			45,100					11,300	14,300							
												14,400							
		Right Shore	10-16-51							6,520	2,720	4,580							
										9,150	1,760	2,940							
											3,360	2,640							
			11-1-51							4,410		2,360							
										1,420		4,430							
										2,700		4,390							
			11-16-51			2,220				1,410	2,280	2,290							
						3,160					2,000	3,220							
						3,340					2,300	4,480							
			11-28-51								965	1,600							83
											827	940							
											1,110	1,030							
			12-12-51					755			31	236				4			194
								55			1,190	815							
											37								
		Left Shore	1-23-52					282			190	224							
								216			210	353							
								475			203	570							
								324			277	323							
											111								
		Right Shore	2-6-52			352		201		160	220	66							40
						206		189			271	302							66
						232		263			274	381							38
			2-20-52			216				163								76	
																		424	
																		96	
			3-5-52			82				86	224	151							42
						59						259							52
						74						400							-14
			3-19-52			44				372	270	271							
											258	392							
											206	470							
			4-9-52			37		-15		294	536	222						14	88
						42				342		375							112
						75				317		192							74
			4-23-52					31		200	434	244							146
								163		53	9	294							255
										37	150	367							314
			5-7-52	726		31		84		183	102	256							
						88		61		119	70	250							
								915		121	48	152							
		Left Shore	8-13-52					6,140		6,760	6,040	3,470							
											4,020	6,630							
												2,850							
Columbia River at Juniper Canyon	C-306	Right Shore	10-2-51								4,410	6,480							
											5,510	903							
			10-16-51			12,600				12,700	2,320	2,720							
						9,160				11,650	2,840								
										8,660	935								
											1,450								
											3,620								
											3,000								
											3,530								
			11-16-51			4,750					1,600	2,760							395
											2,220	3,590							3,780
											2,950								4,550
			11-28-51			137					970	510							398
											114	546							2,590
											278								
			12-12-51			1,610				2,220	1,050	1,330							1,870
						1,860				1,770	1,500								5,520
										1,790									

* Facing Upstream

Table B-8 RADIOACTIVITY OF JUVENILE FISH (ENTIRE) (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY as 10^{-7} uc/gm.																
				SALMONIDAE - Salmon and Trout Family		CATOSTOMIDAE - Sucker Family		CYPRINIDAE - Carp and Minnow Family						GASTEROSTIDAE - Stickleback Family	CENTRARCHIDAE - Bass and Sunfish Family				COTTIDAE Sculpin Family	
Sampling Range	Mileage Index Number	Location of Sample*	Date of Sample	Oncorhyncus tshawytscha (Chinook salmon)	Catostomus sp (Suckers)	Cyprinus carpio (Carp)	Acrocheilus alutaceus (Chiselmouth)	Mylocheilus caurinus (Columbia River chub)	Rhinichthys sp (Dace)	Ptychocheilus oregonensis (Squawfish)	Richardsonius balteatus (Columbia River shiner)	Gasterosteus aculeatus (Three-spined sticklebacks)	Micropterus dolomieu (Smallmouth bass)	Micropterus salmoides (Largemouth bass)	Lepomis sp (Sunfish)	Pomoxis sp (Crappie)	Cottus beldingi (Smooth sculpin)	Cottus sp (Prickly sculpins)
Columbia River at Juniper Canyon (cont'd)	C-306	Right Shore	1-23-52				532			94	402							
							811			161	528							
										260	528							
										137	557							
										234	695							
											430							
			2-6-52		219		410			81	100				73			
					226		364			108	330							
							324			168	187							
			2-20-52				323	345		44	438							
							640	333		66	420							
							510			258	575							
			3-5-52				536	252		190	290							
							503	254		84	425							
							68			184	220							
			3-19-52		382		460	258		176	209							
					276		590			167	259							
					572		690			180	299							
			4-9-52		410		27			124	410				146			
							105			392	832							
							117				650							
			4-23-52		90		121			328	392							195
					45		217			336	430							
					200		93			187	401							
			5-7-52	283	206		114		157	71	320							
							149		209	85	462							
							167			138	344							
			6-18-52		695	75	990		1,020	465								
					685	164	1,475			715								
					790		264			605								
			7-9-52				2,100		3,320	1,310	957							
							1,490			1,440	1,660							
							1,710			1,440	1,770							
			8-6-52				6,180	7,240		6,520	5,700							
								5,280		6,150	7,830							
										4,590	7,500							
		Left Shore	8-13-52		2,830	3,240				4,440	5,750	6,370						
										3,160	4,440	6,570						
										3,740	3,820	6,940						
		Right Shore	9-10-52		8,480					9,700		5,610						
					9,390					10,600		20,600						
										4,450								
			10-29-52		4,280				16,400	3,660							7,640	
					9,900					6,520							10,000	
										4,870							6,800	
			11-17-52						11,600	2,930							3,140	
									8,750	2,240							3,730	
																	3,130	
		Left Shore	12-8-52		1,870					2,190	3,420	1,280					645	2,820
					2,080					2,320	4,460						4,090	2,340
										1,520								
Columbia River above McNary Dam	C-297	Left Shore	10-2-51		9,200					5,160	7,300				11,100			
					6,460					3,890	6,950				17,800			
			10-18-51		6,280		5,150			7,350	6,050							695
					4,080					7,500	6,930							1,420
					6,580					4,890	5,190							
			11-7-51							1,160	3,960							495
										2,890	3,020							
										1,160	4,600							
			11-20-51				676			190	2,180							
							149			368	1,070							
										612	1,490							
			12-5-51				2,260			521	1,690							977
							2,490			845	1,800							
							1,200			1,670	1,980							
			1-30-52		274		701			370	330	272						287
					323		410			218	380							320
										243	338							348
			2-13-52				174	165		90	165	182						
							250			125	320							
							166			139	226							
			2-27-52		234		194	150		108	230						60	
							232			176	171							
							216			141	299							

* Facing Upstream

Table B-8 RADIOACTIVITY OF JUVENILE FISH (ENTIRE) (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY as 10^{-7} μc/gm.															
				SALMONIDAE - Salmon and Trout Family		CATOSTOMIDAE - Sucker Family	CYPRINIDAE - Carp and Minnow Family						GASTEROSTIDAE - Stickleback Family	CENTRARCHIDAE - Bass and Sunfish Family				COTTIDAE Sculpin Family	
Sampling Range	Mileage Index Number	Location of Sample*	Date of Sample	Oncorhynchus tshawytscha (Chinook salmon)		Catostomus sp (Suckers)	Cyprinus carpio (Carp)	Acrocheilus alutaceus (Chiselmouth)	Mylocheilus caurinus (Columbia River chub)	Ramichthys sp (Dace)	Ptychocheilus oregonensis (Squawfish)	Richardsonius balteatus (Columbia River shiner)	Gasterosteus aculeatus (Three-spined stickleback)	Micropterus dolomieu (Smallmouth bass)	Micropterus salmoides (Largemouth bass)	Lepomis sp (Sunfish)	Pomoxis sp (Crappie)	Cottus beldingii (Smoothe sculpin)	Cottus sp (Prickly sculpins)
Columbia River above McNary Dam (cont'd)	C-297	Left Shore	3-12-52			293		331	283	850	80	337							378
										95	111	241							1,360
											174	216							
			3-26-52			139		800			78	284							91
						491		870			136	407							15
								766			278	374							
			4-23-52			865		274		475	143	266							206
						360					244	244							1,000
						1,660					332	475							2,280
			4-30-52	1,320		2,040		255	437	849	206	236							314
						855		895	226	743	115	435							125
						1,030		420			148	446							347
			5-14-52	2,010		210		418		539	73	256							148
				628		1,230		586			144	405							159
				380		1,420		580			177								284
			6-18-52			690		2,900		4,340	1,960	1,420							
						2,420					2,220	2,240							
						2,340					2,620	2,380							
			7-9-52			1,030		1,580			1,270	1,690				2,500			824
								1,430			1,240	1,700				2,610			832
								1,570			1,580								
			8-6-52			4,040		3,540	3,320		2,710	2,960							
						3,780		2,390			2,940								
						6,000		3,250			3,900								
			9-10-52			5,650	2,960	8,130	3,560		3,450	6,460	3,180		4,770	3,900			
						4,450		2,380	2,800		4,070	8,830	5,350			3,360			
						3,560		2,380	3,190		3,960	8,480							
			10-15-52			13,600		4,300		15,600	4,860	10,400						5,960	5,230
						12,300		5,340		15,000	6,600	9,230							
						8,980		7,830		15,300	5,850	9,350							
			11-5-52								12,700	8,000						3,660	
											5,350	8,940							
											3,000	3,350							
			12-9-52			3,320		4,050			2,090	3,520							
								2,500			1,880	4,070							
								2,960			2,460	4,360							
			1-7-53							1,660	621	1,570				163			
											1,043	2,010							
											965	1,910							
			3-4-53					1,190			565	525							
								1,380			460	937							
								1,380				915							
Columbia River at Paterson, Wash.	C-278		10-2-51			8,750					6,600	7,650							
						9,730					6,800	8,750							
			10-18-51			6,600					3,650	5,820							
											3,950	5,500							
											3,830	7,890							
												5,800							
			11-7-51			6,250		8,100		5,170	2,170	3,700							3,620
						5,330		2,300		5,570	1,530	4,030							2,380
						11,200		3,100		7,300	2,280	3,560							
			11-20-51			2,650		3,120	2,180	3,330	2,040	2,300							
						3,860			2,360		1,660	2,010							
									2,120		1,740	2,010							
			12-5-51					1,340	675		830	1,040							
											921	1,280							
											426	1,380							
			1-30-52								97	342							
											242	296							
											244	338							
			2-13-52								84	296						1,050	730
											107	133						1,470	
											104	193							
			2-27-52					66	89		20	278							
								310	82		5	171							
								150	85		70	254							
			3-12-52			113		470	77		93	320							930
						424					113	295							
											280	270							
			3-26-52					435			87	395							
								440			86	290							
								590				330							
			4-23-52			525		505		230	222	396							396
						283				440	207	358							88
											300	224							

* Facing Upstream

Table B-8 RADIOACTIVITY OF JUVENILE FISH (ENTIRE) (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY as 10^{-7} μc/gm.																	
							CYPRINIDAE - Carp and Minnow Family							CENTRARCHIDAE - Bass and Sunfish Family				COTTIDAE Sculpin Family	
Sampling Range	Mileage Index Number	Location of Sample*	Date of Sample	SALMONIDAE - Salmon and Trout Family: Oncorhyncus tshawytscha (Chinook salmon)	CATOSTOMIDAE - Sucker Family: Catostomus sp (Suckers)	Cyprinus carpio (Carp)	Acrocheilus alutaceus (Chiselmouth)	Mylocheilus caurinus (Columbia River chub)	Rhinichthys sp (Dace)	Ptychocheilus oregonensis (Squawfish)	Richardsonius balteatus (Columbia River shiner)	GASTEROSTIDAE - Stickleback Family: Gasterosteus aculeatus (Three-spined stickleback)	Micropterus dolomieu (Smallmouth bass)	Micropterus salmoides (Largemouth bass)	Lepomis sp (Sunfish)	Pomoxis sp (Crappie)	Cottus beldingi (Smoothe sculpin)	Cottus sp (Prickly sculpins)
Columbia River at Paterson, Wash (cont'd)	C-278	Left Shore	4-30-52					550		102	214		55					
										121	274							
										321	321							
			5-14-52		1,085		1,270			159	376							
					1,040		930			252	384							
					465		900			157	384							
			6-18-52		1,310		2,060		2,240	915	1,010							
					1,540		1,680			1,310	724							
					1,970		1,880			1,160	973							
			7-9-52		1,870		1,420		2,750	845	1,050							
					1,210		1,530		3,600	875	1,380							
					935		1,490		3,640	1,750								
			8-6-52		3,100		4,100	2,780		1,780	2,580		1,990					
					3,280		860			1,620			2,810					
							4,520			2,740			1,840					
			9-10-52		12,800		2,480	3,240	8,320	2,140	4,040		4,200				2,540	
					17,700		3,950		6,200	4,800	7,300		4,109				8,380	
					11,800		3,620		9,200	4,220	5,900							
			10-15-52		14,200		4,250	4,840	14,200	2,790	6,600						3,840	
					21,200		1,880	5,620	7,900	5,820	7,300							
					10,400		1,550	4,450	11,600	5,600	11,700							
			11-5-52		26,900		1,940		9,150	4,160	6,120						6,850	
					25,800				6,200	1,160	6,160							
					17,700				11,300		6,930							
			12-17-52							1,270	2,660							
										1,290	2,640							
										770	2,340							
			2-11-53				740			281	690							
							1,070			428	710							
							1,090			372								
			3-4-53	1,060			620			361	505							
										282	680							
										236	650							
Columbia River below Corbett, Ore.	C-125	Right Shore	11-12-52	90						1,400	1,200	3,000						330
										470								
										1,400								
		Right Shore Slough		33							59							
										150	310	85						
		Left Shore	3-31-53	110					240	57								
				1,200					190	110								140
				490					260	110								350
									400	280								
Columbia River at Astoria, Ore.	C-13	Right Shore	3-30-53	440														
				400														880
				320														1,300
				260														740
																		750
TRIBUTARIES																		
Yakima River at Kinna, Wash.	CY-364	Left Shore	10-18-51		40 ± 20		-5 ± 29		21 ± 40	49 ± 15	47 ± 13							
					-10 ± 15		44 ± 35		45 ± 28	39 ± 14	57 ± 13							
					12 ± 7		46 ± 36		59 ± 39	81 ± 21	77 ± 9							
Yakima River at Enterprise, Wash.	CY-343	Right Shore	10-18-51		9 ± 13		91 ± 42		1 ± 13	100 ± 47	290 ± 19		-20 ± 15	1 ± 13				
					14 ± 16		8 ± 17		-25 ± 20	810 ± 70	160 ± 95		11 ± 16					
					31 ± 12		78 ± 25		-29 ± 23	280 ± 27			13 ± 18					
									-18 ± 19									
									-19 ± 14									
									4 ± 14									
			11-7-51		60 ± 12				72 ± 25	400 ± 25	56 ± 12							
									7 ± 11	270 ± 56	85 ± 16							
									96 ± 13	100 ± 44	80 ± 20							

* Facing Upstream

Table B-8 RADIOACTIVITY OF JUVENILE FISH (ENTIRE) (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY as 10^{-7} μc/gm.																	
							CYPRINIDAE - Carp and Minnow Family							CENTRARCHIDAE - Bass and Sunfish Family				COTTIDAE Sculpin Family	
Sampling Range	Mileage Index Number	Location of Sample*	Date of Sample	SALMONIDAE - Salmon and Trout Family		CATOSTOMIDAE - Sucker Family							GASTEROSTIDAE - Stickleback Family						
					Oncorhyncus tshawytscha (Chinook salmon)	Catostomus sp (Suckers)	Cyprinus carpio (Carp)	Acrocheilus alutaceus (Chiselmouth)	Mylocheilus caurinus (Columbia River chub)	Rhinichthys sp (Dace)	Ptychocheilus oregonensis (Squawfish)	Richardsonius balteatus (Columbia River shiner)	Gasterosteus aculeatus (Three-spined stickleback)	Micropterus dolomieu (Smallmouth bass)	Micropterus salmoides (Largemouth bass)	Lepomis sp (Sunfish)	Pomoxis sp (Crappie)	Cottus beldingii (Smoothe sculpin)	Cottus sp (Prickly sculpins)
Yakima River at Enterprise, Wash. (cont'd)	CY-343	Right Shore	12-5-51					11 ± 16			10 ± 11	25 ± 13		70 ± 56					
								14 ± 14			18 ± 10	138 ± 16		27 ± 14					
								22 ± 12			290 ± 23	26 ± 14							
			1-30-52					3 ± 17		3 ± 15	8 ± 11	8 ± 8				7 ± 11			
											42 ± 13	15 ± 9							
											12 ± 11	4 ± 10							
			2-26-52			39 ± 22		34 ± 15		19 ± 23	48 ± 14	21 ± 17							
						43 ± 18		24 ± 15			25 ± 10	17 ± 13							
												18 ± 11							
			3-26-52					16 ± 13		2 ± 18	12 ± 15	10 ± 22							
								16 ± 23		-18 ± 28	1 ± 12	12 ± 17							
								9 ± 37		-8 ± 29	19 ± 23	-9 ± 20							
			4-30-52	95 ± 21		37 ± 7		33 ± 13		33 ± 16	34 ± 16	38 ± 14		20 ± 13					
				24 ± 15				26 ± 14		0 ± 14	32 ± 23	41 ± 12							
								20 ± 12		16 ± 13	26 ± 11	47 ± 14							
			6-23-52					31 ± 10		1 ± 13	24 ± 9			46 ± 7					
								40 ± 17		0 ± 13	17 ± 14								
										23 ± 13	16 ± 10								
			9-9-52				26 ± 13	86 ± 13		18 ± 10	91 ± 18	137 ± 30		62 ± 14					
								46 ± 19		32 ± 24	110 ± 32			82 ± 23					
								87 ± 21		9 ± 39	215 ± 24			30 ± 24					
			11-6-52			28 ± 9	32 ± 5	51 ± 12			112 ± 13	2640 ± 80		39 ± 13					
						1650 ± 70		760 ± 38			890 ± 42	2120 ± 80		28 ± 11					
								136 ± 22			1560 ± 80	1080 ± 100							
			3-16-53					25 ± 12			68 ± 20	16 ± 6		26 ± 15					
								18 ± 7			54 ± 18	41 ± 10							
											340 ± 15								
Yakima River at Richland Highway Bridge	CY-339	Left Shore	10-18-51			6980 ± 480	90 ± 9			94 ± 94	4200 ± 150	5690 ± 200		280 ± 32	407 ± 56				
							35 ± 7			50 ± 24	2800 ± 90	2640 ± 90		198 ± 17					
											8120 ± 240			215 ± 21					
			11-20-51			8 ± 30	50 ± 18				150 ± 35	679 ± 55							
											592 ± 51	1010 ± 70							
											169 ± 40	359 ± 43							
			12-5-51				28 ± 8	28 ± 17			408 ± 35	411 ± 33							
							34 ± 7	37 ± 23			187 ± 19	250 ± 21							
			3-12-62				17 ± 6	37 ± 12	55 ± 25		26 ± 9	-4 ± 12				22 ± 17			
							18 ± 7	11 ± 11			38 ± 18	11 ± 16				51 ± 34			
								24 ± 14			29 ± 20	10 ± 16							
			5-7-52				17 ± 15	37 ± 14		-1 ± 34	63 ± 13					26 ± 14			
							5 ± 28	65 ± 19			36 ± 12					17 ± 13			
											65 ± 16								
			7-23-52					38 ± 8			690 ± 30	173 ± 13			47 ± 13				
								31 ± 8			770 ± 42	474 ± 25			48 ± 16				
								49 ± 30				130 ± 18							
			10-29-52								6150 ± 230			120 ± 14	268 ± 15	220 ± 41			
											8010 ± 250			160 ± 16	847 ± 23	93 ± 22			
														68 ± 18		164 ± 26			
Snake River at Page, Wash.	CS-342		10-31-51							32 ± 13	116 ± 30								89 ± 30
										65 ± 14									
										65 ± 15									
			11-28-51			-8 ± 12				19 ± 15	206 ± 24	19 ± 21							5 ± 7
						22 ± 12				32 ± 21	39 ± 15								
										16 ± 18	-44 ± 14								
			3-19-52			19 ± 14		16 ± 20		15 ± 21	-22 ± 21	23 ± 9							-2 ± 8
						-10 ± 19		13 ± 16		7 ± 35	3 ± 14	25 ± 18							30 ± 24
						-6 ± 42		11 ± 18			4 ± 17	20 ± 26							
			3-26-53	-28 ± 48		21 ± 15		30 ± 16		18 ± 29	30 ± 9	69 ± 14					25 ± 18		
				87 ± 36		45 ± 19		37 ± 21			45 ± 11	93 ± 15							
											23 ± 14	97 ± 17							
											-17 ± 13	133 ± 16							
Snake River near the mouth	CS-325		10-16-51								3570 ± 90	1000 ± 40							
											1070 ± 50	1360 ± 60							
											2440 ± 60	770 ± 35							
												1270 ± 70							
			12-12-51					180 ± 24			320 ± 30	236 ± 20							
								85 ± 38			115 ± 29	242 ± 41							
								84 ± 41			46 ± 22	131 ± 28							

* Facing Upstream

Table B-8 - RADIOACTIVITY OF JUVENILE FISH (ENTIRE) (continued)

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY as 10^{-7} μc/gm.																	
				SALMONIDAE - Salmon and Trout Family		GATOSTOMIDAE - Sucker Family		CYPRINIDAE - Carp and Minnow Family						GASTEROSTIDAE - Stickleback Family	CENTRARCHIDAE - Bass and Sunfish Family				COTTIDAE Sculpin Family	
Sampling Range	Mileage Index Number	Location of Sample*	Date of Sample	Oncorhyncus tshawytscha (Chinook salmon)		Catostomus sp (Suckers)		Cyprinus carpio (Carp)	Acrocheilus alutaceus (Chiselmouth)	Mylocheilus caurinus (Columbia River chub)	Rhinichthys sp (Dace)	Ptychocheilus oregonensis (Squawfish)	Richardsonius balteatus (Columbia River shiner)	Gasterosteus aculeatus (Three-spined sticklebacks)	Micropterus dolomieu (Smallmouth bass)	Micropterus salmoides (Largemouth bass)	Lepomis sp (Sunfish)	Pomoxis sp (Crappie)	Cottus baldingii (Smoothe sculpin)	Cottus sp (Prickly sculpins)
Snake River near the mouth (cont'd)	CS-325	Left Shore	1-23-52						33 ± 21			9 ± 24	27 ± 13							
									28 ± 26			29 ± 16	25 ± 17							
									71 ± 21			24 ± 16	24 ± 16							
			2-6-62			10 ± 8			29 ± 9			29 ± 13	23 ± 9		17 ± 8				22 ± 9	
						18 ± 13			27 ± 27				4 ± 14		34 ± 44				18 ± 8	
						86 ± 17			83 ± 23				18 ± 13						31 ± 15	
			3-5-52						24 ± 16			8 ± 16	30 ± 10							
									342 ± 41			-5 ± 19	14 ± 15							
									5 ± 18			1 ± 19	24 ± 21							
			4-30-52						11 ± 12		-10 ± 18	2 ± 11	105 ± 35							-10 ± 15
																				12 ± 16
			6-25-62						51 ± 19		30 ± 23	129 ± 22	800 ± 45							
									33 ± 16			85 ± 22	1400 ± 80							
									49 ± 18											
			7-23-52			87 ± 19			49 ± 18	40 ± 16		41 ± 11	117 ± 28							
						22 ± 17			19 ± 11			62 ± 14								
									41 ± 14			72 ± 13								
			8-5-52						480 ± 130			201 ± 24								
									453 ± 35			190 ± 24								
									490 ± 30			560 ± 33								
			10-8-52			1300 ± 280			1620 ± 180		194 ± 23	1430 ± 60	2120 ± 90							
						1410 ± 280			500 ± 30			770 ± 90	2400 ± 100							
									494 ± 30			267 ± 30	1630 ± 90							
			11-4-52						126 ± 55			1120 ± 60	1630 ± 70							
									130 ± 62			2980 ± 120	4140 ± 150							
												3530 ± 100	2090 ± 110							
Walla Walla River at old Highway Crossing	CWw-322		10-2-51			44 ± 10					100 ± 36				21 ± 9					
			11-14-51								4 ± 12				35 ± 11					
			3-5-52			33 ± 9			28 ± 12		4 ± 12	10 ± 15	30 ± 30		29 ± 17					
						21 ± 10			11 ± 16		20 ± 20	15 ± 13								
									16 ± 19		16 ± 9									
			4-30-52			-10 ± 12			1 ± 7			27 ± 14	-15 ± 21							
						0 ± 9			2 ± 10											
									18 ± 9											
			6-25-52	67 ± 24		33 ± 9			34 ± 14		5 ± 14	26 ± 10	22 ± 9							
									40 ± 14		25 ± 14	43 ± 14	52 ± 11							
									107 ± 18		27 ± 15	44 ± 18	72 ± 16							
			7-23-52			11 ± 10			24 ± 16		8 ± 7	12 ± 11	68 ± 11							
						13 ± 11			13 ± 13		12 ± 11	13 ± 38	48 ± 12							
									84 ± 17				96 ± 18							
			8-13-52						48 ± 10		20 ± 16	44 ± 8	36 ± 8							
									58 ± 13		32 ± 16	133 ± 15	382 ± 25							
									172 ± 20			37 ± 14	286 ± 22							
			10-29-52								16 ± 7									
											21 ± 14									
											151 ± 22									
			11-17-52			26 ± 8			20 ± 7		14 ± 11	1110 ± 40								
									76 ± 13		22 ± 7	50 ± 9								
									164 ± 16		14 ± 11									
Walla Walla River at U.S. Highway 395 Bridge	CWw-318		5-14-52			165 ± 19			27 ± 13		30 ± 21	22 ± 13	81 ± 17							
						49 ± 13			41 ± 12			20 ± 14	64 ± 17							
						25 ± 14			-8 ± 12			24 ± 14								

* Facing Upstream

Table B-9 RADIOACTIVITY OF ADULT FISH - INDIVIDUAL PARTS

SAMPLE DATA								GROSS BETA ACTIVITY DENSITY in 10^{-7} μc/gram								
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample	Kind of Fish	Length of Fish Millimeters	Weight of Fish Grams	Sex and Condition (1)	Skin	Muscle	Scales	Bone	Ovary	Testes	Kidney	Liver	Stomach and Intestinal Contents
Columbia River above Trinidad, Wash.	C-445	Right Shore	1-12-53	Whitefish - Prosopium Williamsoni	430	900	Ud-F	78±26	16±14	56±60	4±46	17±44		18±22	25±17	23±27
					320	260	Sp-F		82±16	160±64		140±21			110±34	
					320	215	Ud-F		21±15	46±63					73±57	30±38
					305	220	Ud-F		26±11	-31±28					5±71	
					300	185	Ud-F		82±12	160±46					75±40	
					310	215	Ud-F		28±11	-9±55					10±51	82±24
					290	220	Ud-F		15±27	12±60					85±64	
					290	220	Ud-F		36±17	110±100					79±84	
					290	200	Ud-F		31±19	24±100					24±50	3±22
					290	180	Ud-F			94±81					-57±66	
					290	180	D-M		20±17	3±55			39±28		16±57	
					290	180	Ud-F		43±14	43±34					43±31	
					280	220	Ud-M		32±29	-13±67					-33±60	
					280	170	D-M		53±19	13±46					0±70	
					270	170	Ud-F		33±19	33±77					30±66	
					255	170	Ud-F		42±25	23±60	-38±130	2±40		170±250	37±86	170±130
					330	290	Ud-F		8± 4	-7±10					0± 9	
					320	255	Ud-F		13± 3	52±13					46± 9	
					310	250	Ud-F		15± 4	10± 9					4± 8	16± 6
					270	155	Ud-F		17± 4	-5±11					-1±18	
Columbia River above Vantage, Wash.	C-424	Right Shore	1-13-53	Whitefish - Prosopium Williamsoni	345	450	Ud-M	-13±57	25±10	44±34	2±33		23±72	7±51	27	-9±27
					280	220	Ud-F	-62±57	52±25	43±57	7±58	18±30		-17±140	23	27±27
					240	110	Ud-F		39±20	20±62					27	
					240	110	Ud-M		26±18	85±65					58	
					215	110	Ud-M		5±16	-22±45					110	
Columbia River above Beverly, Wash.	C-414	Right Shore	1-13-53	Whitefish - Prosopium Williamsoni	330	280	Ud-F	16±48	17±16	-15±48	15±63	57±57		-29±97	68	3±61
					305	220	Ud-F		12±28	7±71					37	63±73
					305	220	Ud-F		-1±25	34±58					72	-92±100
					280	170	D-M		24±26	34±59			31±55		60	33±79
					280	170	Ud-F	14±59	15±17	-17±52	27±51	100±102		-13±90	23	63±88
Columbia River at Priest Rapids, Wash.	C-400	Left Shore	11-6-51	Sucker, C.A.-Catostomus macrocheilus	310	515	Ud-F		23± 7	33±29		13± 7				
Columbia River at Hanford Ferry Crossing	C-362	Left Shore Slough	4-10-52	Bass, L.M. - Micropterus salmoides	395	900	Ud-M	16	41	11	11		47	28	40	73
					405	1,125	Ud-M	10	28	5	-1		30	15	21	41
			4-4-52	Bass, S.M. - Micropterus dolomieu	395	925	Ud-M	7	5	10	-19		24		32	
					430	1,150	Ud-F	-11	37	37	34	23		44	34	445
			4-10-52		380	925	D-F	9	44	20	16	55		11	44	26
					430	1,200	Ud-M	-2	51	-44	1		29	54	17	51
			4-17-52		400	1,125	D-M	-9	27	-34	-22		39	42	30	190
					405	1,150	D-F	-6	12	9	-37	76		30	42	176
					430	1,600	D-F	6		-36	-11	48		37	26	130
					370	750	D-F	165	42	-8	13	33		-67	140	9,200
			4-26-52		355	800	D-F	54	21	0	-72	19		65	-9	90
					470	1,850	D-F	22	17	43	35			48		16,000
					405	1,125	D-F	26	-11	0	-3	53		-66	47	20
			7-15-52		320	520	Ud-F	176		3,130	2,680	670			1,540	
			7-22-52		330	550	Ud-M	185	640	3,020	2,640		720	1,580	1,860	4,110
					400	800	Pd-F	196	455	1,690	1,180	1,300		1,350	2,090	4,540
			7-31-52		300	350	Ud-F	259	641	4,450	1,320	4,170		1,720	1,360	2,630
			9-17-52		470	1,600	Ud-F	560	630	5,280	3,120	980		2,500	4,000	82,400
					310	500	Ud-M	1,400	2,040	32,200	35,200		8,380	7,070	8,400	15,700
					360	700	Ud-F	2,500	870	8,530	10,600	4,940			3,270	77,900
					380	750	Ud-F	650	1,110	11,500	11,900	2,750		2,870	3,940	7,030
					310	500	Ud-M	630	1,170	10,200	14,600		3,620	3,980	3,500	7,370
			10-21-52		470	1,800	Ud-F		414	5,900	4,950	4,120		3,580	2,590	8,790
					340	600	Ud-F	452	720	6,150	4,680	3,170		2,150	3,110	
			10-22-52		480	1,800	Ud-F	700	990	5,420	2,940	2,750		3,610	3,510	19,000
			10-23-52		470	2,000	Pd-F	380	473	2,160	3,160	3,200		1,910	2,810	
					360	800	Ud-M	550	727	2,800	6,650		3,060	2,060	2,700	
					320	475	Ud-M	2,220	1,820	22,600	21,300		5,140	5,310	7,850	28,000
					325	525	Ud-M	606	878	13,200	9,160		2,710	2,700	3,860	
					350	700	Ud-F	470	697	8,400	7,980	2,970		1,720	2,090	5,290
					330	550	Ud-M	640	1,030	16,500	12,600		3,740	4,270	3,430	9,900
			11-21-52		500	1,900	Ud-F	117	180	1,110	875	268		870	760	
					340	600	Ud-M	295	445	4,150	2,490		1,080	1,880	2,070	
			11-26-52		450	1,700	Pd-F	220	483	2,580	2,610	695		3,170	1,460	
					460	1,500	Pd-F	260	424	1,460	1,650	760		1,200	2,020	
			12-15-52		430	1,400	Pd-F	102	265	820	755	503		753	715	

(1) F = Female; M = Male; Pd = Partly developed; Ud = Undeveloped; D = Developed; Sp = Spent; Juv. = Juvenile

Table B-9 RADIOACTIVITY OF ADULT FISH - INDIVIDUAL PARTS (continued)

SAMPLE DATA								GROSS BETA ACTIVITY DENSITY in 10^{-7} μc/gram								
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample	Kind of Fish	Length of Fish Millimeters	Weight of Fish Grams	Sex and Condition (1)	Skin	Muscle	Scales	Bone	Ovary	Testes	Kidney	Liver	Stomach and Intestinal Contents
Columbia River at Hanford Ferry Crossing (cont'd)	C-362	Left Shore Slough	5-19-52	Carp - Cyprinius carpio	710	2,950	D-F	113	160	290	140	600		425	760	535
			5-21-52		625	2,950	D-F	105	185	180	137	350		400	550	670
					460	1,125	D-M	104	180	210	100		605	305	370	85
			5-26-52		660	3,400	D-F	88	90	95	70	175		300	360	125
					585	1,800	D-F	89	100	214	38	220		250	410	370
					460	900	D-M	110	164	283	193		650	300	290	540
					535	1,700	D-F	95	90	140	33	330		380	585	620
			6-16-52		610	3,630	D-M	210	130	570	300		260	1,030	930	3,120
			6-23-52		585	3,630	D-M	255	300	700	350		750	1,400	1,780	3,740
			7-1-52		680	3,300	D-F	240	276	530	170	520		1,000	1,590	2,140
			7-8-52		480	1,250	D-M	110	233	1,050	240		2,270	870	1,220	2,400
					460	1,100	Sp-F	640	610	1,560	600	1,460		2,240	2,890	1,890
			7-21-52		450	1,200	D-F	150	262	605	700	880		700	890	800
			10-23-52		300	400	Ud-M	5,200	6,200	68,900	69,300			16,200	15,900	26,520
					480	1,750	D-F	1,530	2,550	7,160	7,300	3,430		6,920	9,350	8,800
					570	2,100	Pd-M	985	3,050	5,050	2,500		11,200	7,270	7,170	18,540
			11-21-52		500	1,700	D-F	660	1,390	4,170	5,900	5,000		6,990	8,990	9,100
					530	1,850	D-F	1,560	1,600	5,710	5,600	4,470		9,190	16,400	
			11-24-52		510	1,800	D-M	2,940	1,350	7,520	9,100		4,410	5,450	6,110	
			12-15-52		510	2,200	Pd-F	895	1,410	2,350	1,650	2,210		6,970	5,510	
					455	1,600	D-F	710	727	2,730	2,030	1,690		3,790	3,460	2,620
			2-18-53		560	1,900	Pd-M	110	64	93	155		78	505	323	940
			3-13-53		490	2,000	D-F	98		470	260	180		810	1,080	
					460	1,600	D-F		2,400	14,200					2,300	
			7-22-52	Chiselmouth - Acrocheilus alutaceus	310	370	Ud-M	1,360	720	7,750	2,280			4,970	7,880	9,800
			10-23-52	Perch, Yellow - Perca flavescens	330	575	Pd-F	515	460	3,860	2,780	2,040			2,360	7,020
					330	525	Pd-F	336	435	4,470	2,220	2,600			3,480	-155
			6-27-52	Salmon, Blueback - Oncorhynchus nerka nerka	535	1,250	Pd-M	-3	32	68	-6		40	52	37	
					535	1,275	Pd-F	-10	22	63	20	24		11	41	
					510	1,200	Pd-M	8	26	125	14		53	31	44	
					510	1,025	Pd-F	-35	26	87	12	35		14	20	
					485	925	Pd-M	-55	42	-21	0		33	53	14	
			7-1-52		530	1,600	Pd-M	65	54	125	76		100	83	65	
			7-15-52		530	1,450	Pd-M	30	20	114	43			55	44	
			7-22-52		520	1,670	Pd-F	15	10	53	23	21		35	37	
			4-4-52	Squawfish - Ptychocheilus oregonensis	355	325	Ud-M	24	41	87	34		120	33	71	150
			6-24-52		330	425	D-F	190	178		630	860		615	2,060	1,240
					330	400	D-F	475	260	1,500	820	480		790	1,340	1,500
			6-27-52		460	1,025	D-F	105	43	140	19	110		150	267	87
			7-1-52		430	900	D-F	140	87	940	203	470		267	475	404
			7-15-52		360	350	Ud-M	201	97	850	52		150	156	89	198
			7-29-52		480	980	Ud-F	429	162	1,800	820	396		505	444	
			7-31-52		360	400	Ud-M	127	193	640	390		212	473	495	505
					350	350	Ud-F	283	540	3,460	2,530	410		1,790	1,910	11,400
			10-22-52		430	650	Ud-F	335	905	6,830	3,780	1,750		2,320	3,150	3,520
			10-23-52		450	850	Pd-F	273	386	1,900	860	614		459	975	690
			11-21-52		440	900	Ud-F	184	315	1,600	1,400	813		843	1,290	
					480	1,000	Ud-F	335	515	2,120	2,140	1,230		1,970	2,670	
			11-24-52		500	1,100	Ud-F	633	470	3,300	2,090	3,580		2,330	2,550	
			12-15-52		425	800	Ud-F	283	218	1,050	454	557		830	890	
					430	800	Ud-F	299	533	1,580	980	610		1,360	1,480	
			1-27-53		380	500	Ud-F	271	116	660	380	177		339	424	
			1-28-53		430	800	Ud-F	212	190	480	700	298		510	550	
					470	900	Ud-F	228	81	433	190	192		315	333	277
			2-18-53		440	800	Ud-F	158	74	250	150	96		160	166	
					450	850	Pd-F	104	66	180	43	92		92	160	
			3-13-53		435	770	Ud-F	88	71	725	76	106		196	473	
					430	900	Pd-F		108	460					515	
					400	700	Pd-F		91	180					404	

(1) F = Female; M = Male; Pd = Partly developed; Ud = Undeveloped; D = Developed; Sp = Spent; Juv. = Juvenile

Table B-9 RADIOACTIVITY OF ADULT FISH - INDIVIDUAL PARTS (continued)

SAMPLE DATA								GROSS BETA ACTIVITY DENSITY in 10^{-7} μc/gram								
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample	Kind of Fish	Length of Fish Millimeters	Weight of Fish Grams	Sex and Condition (1)	Skin	Muscle	Scales	Bone	Ovary	Testes	Kidney	Liver	Stomach and Intestinal Contents
Columbia River at Hanford Ferry Crossing (cont'd)	C-362	Left Shore Slough	6-23-52	Sucker, Coarse-Scaled - Catostomus macrocheilus	610	1,350	Ud-F	116	56	253						
			6-24-52		305	350	Ud-F	1,480	1,080	16,100	10,100	1,910		5,860	5,160	5,200
					485	1,000	Ud-F	227	120	1,620	1,290	530		2,460	646	2,670
			6-27-52		470	1,050	D-F	810	310	4,160	1,580	2,920		1,930	5,620	8,700
				Sucker, Fine Scaled - s. Catostomus syncheilus	445	900	Ud-F	7,220	2,300	16,000	2,960	5,500		13,100	14,300	10,800
			7-1-52	Sucker, Coarse-Scaled - Catostomus macrocheilus	470	980	Ud-F	838	474	3,740	2,100	4,960		3,710	4,570	7,720
				Sucker, Fine Scaled - Catostomus syncheilus	330	400	Ud-F	5,400	3,780	33,600	26,700	5,580		9,340	20,500	15,500
			7-15-52	Sucker, Coarse-Scaled - Catostomus macrocheilus	465	1,000	Sp-F	2,560	3,390	12,900	12,700	6,260		11,300	14,600	17,300
					490	1,000	Sp-M	2,230	980	15,200	4,120		720	8,020		20,700
				Sucker, Fine Scaled - Catostomus syncheilus	410	750	Sp-M	11,700	7,700	41,400	11,800		1,380	32,900	34,600	36,800
					460	975	Sp-F		474	4,710	1,770	1,380		2,530	2,960	7,250
			7-22-52	Sucker, Coarse-Scaled - Catostomus macrocheilus	500	980	Sp-F	1,320	1,810	16,800	4,670	5,660		30,500	13,700	31,000
					460	875	D-M	384	1,070	16,100	1,860		177	1,920	382	10,900
				Sucker, Fine Scaled - Catostomus syncheilus	360	510	Sp-M	7,630	11,600	62,200	50,200		18,800	36,600	53,900	31,900
			7-29-52	Sucker, Coarse Scaled - Catostomus macrocheilus	450	1,000	Sp-M		1,330	9,400	4,370		1,690	8,790	12,300	21,800
					430	930	Sp-M	1,100	1,390	18,400	8,670		4,850	9,700	9,750	29,500
				Sucker, Fine Scaled - Catostomus syncheilus	420	850	Sp-F	4,800	6,610	63,900	35,900	75,500		24,200	33,100	31,600
			8-14-52	Sucker, Coarse Scaled - Catostomus macrocheilus	470	1,000	Ud-F	1,890	3,820	22,000	17,300	8,930			17,400	39,700
					460	850	Ud-M	3,070	5,050	22,900	11,600		21,000	26,100	22,600	51,600
					430	800	Ud-M	3,880		27,000	20,400		20,200	27,900	32,700	52,900
					430	900	Sp-F	2,480	3,070	23,900	13,700	6,360		13,500	17,800	36,500
					450	900	Ud-M	4,640	4,290	31,600	18,700		15,900	23,500	22,600	48,700
			9-17-52		410	900	D-M		3,790	33,000	17,300		55,600	21,600	19,200	34,500
					450	1,000	D-M	3,990	3,370	31,600	18,500		66,700	22,900	22,400	37,400
					440	900	Ud-F	2,340	2,930	45,400	20,300	9,290		17,300	11,500	15,400
					440	950	Ud-F	2,810	5,600	30,100	34,500	7,980		25,300	30,700	19,900
			10-21-52		450	900	Ud-M	3,330	6,010	46,400	40,600			30,500	26,900	50,000
					470	1,000	Ud-F	2,540	4,550	39,300	34,500	8,990		24,200	33,700	10,700
				Sucker, Fine Scaled - Catostomus syncheilus	460	1,200	D-M	3,700	10,500	25,700	15,300		28,900	22,800	18,100	19,400
					470	1,200	D-M	2,500	5,660	19,600	11,100		38,500	11,900	13,000	39,400
			10-23-52	Sucker, Coarse Scaled - Catostomus macrocheilus	410	800	D-M	6,750	8,840	50,400	42,200		23,200	28,600	26,100	
					440	1,000	Pd-F	5,100	6,670	53,000	29,800	24,800		19,100	30,900	51,200
				Sucker, Fine Scaled - Catostomus syncheilus	480	1,300	D-M	5,000	6,360	44,400	7,330		56,600	29,300	33,900	42,800
			11-21-52	Sucker, Coarse Scaled - Catostomus macrocheilus	450	900	U-M	3,490	3,000	31,600	14,000			20,200	33,200	44,300
					430	850	Ud-M	3,350	3,070	40,500	24,100		1,610	10,400	23,000	31,200
			11-24-52		490	1,200	Ud-M		1,610	4,600	5,120		2,230	6,970	6,060	
				Sucker, Fine Scaled - Catostomus syncheilus	500	1,000	Pd-F	4,620	4,290	26,800	9,800	11,900		24,600	62,100	
			12-15-52	Sucker, Coarse Scaled - Catostomus macrocheilus	420	700	Ud-M	986	3,230	22,200	16,900		820	14,800	17,700	
					570	1,800	Ud-F	891	810	4,340	2,180	1,810		4,410	6,120	11,800
			1-27-53		350	450	Ud-M	3,510	1,360	17,900	7,040		914	10,000	14,700	83,100
			2-18-53		430	700	Ud-M	2,590	1,230	21,800	8,410		3,880	15,200	18,300	24,500
			3-13-53		610	2,500	D-F	179	168	930	366			1,040	1,540	509
					480	1,400	D-F		7,730	26,100					44,200	
				Sucker, Fine Scaled - Catostomus syncheilus	450	1,300	Ud-F	3,870	2,440	17,600	7,060	3,780		19,200	12,700	13,200
					490	1,500	D-F		8,930	32,600		9,180			65,200	
		Left Shore Slough	6-27-52	Whitefish - Prosopium williamsoni	445	800	Ud-F	159	110	810	417	368		383	486	3,820
					430	725	Ud-F	121	105	1,400	672	484		578	645	
			3-13-53		340	355	Ud-F	470	833	2,580	404	1,840		2,740	3,580	15,700
Columbia River at Richland, Wash.	C-339	Left Shore	2-18-52	Bass, L.M. - Micropterus salmoides	120	23	Juv.	59	55	36						17
		Mid-stream	9-29-51	Trout, Steelhead - Salmo gairdnerii	635	2,500	Ud-F		30	25		24		20	186	
					585	1,815	Pd-M		33	124			59	153	61	
		Left Shore	2-2-52	Whitefish - Prosopium williamsoni	305	230	Ud-F		2,250	18,300		5,230				6,920
					305	230	Ud-M		1,130	13,200						3,770
					280	200	Ud-M		1,100	12,000						2,970
Columbia River above Kennewick Wash.	C-330	Right Shore	2-18-52	Carp - Cyprinus carpio	115	30	Juv.		45	33						131
					100	25	Juv.		20	95						58
			6-9-52		560	1,800	D-M	93	56	212	67		113	234	295	1,480
					560	1,575	D-F	28	52	25	-10	48		75	78	100
Columbia River below Pasco, Wash.	C-326	Mid-Stream	7-13-52	Salmon, Chinook - Oncorhynchus tshawytscha	890	7,500	Pd-F	20	18	27	15	17		22	33	
		Mid-stream	7-15-52	Squawfish - Ptychocheilus oregonensis	250	130	Ud-F	111	118	466	347	56		196	154	

(1) F = Female; M = Male; Pd = Partly developed; Ud = Undeveloped; D = Developed; Sp = Spent; Juv. = Juvenile

Table B-9 RADIOACTIVITY OF ADULT FISH - INDIVIDUAL PARTS (continued)

SAMPLE DATA								GROSS BETA ACTIVITY DENSITY in 10^{-7} μc/gram								
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample	Kind of Fish	Length of Fish Millimeters	Weight of Fish Grams	Sex and Condition (1)	Skin	Muscle	Scales	Bone	Ovary	Testes	Kidney	Liver	Stomach and Intestinal Contents
Columbia River below Pasco, Wash. (cont'd)	C-326	Mid-stream	8-3-52	Trout, Steelhead - Salmo gairdnerii	560	2,200	Ud-F	42	31	22	6	26		53	22	
			8-8-52		635	2,900	Ud-M	15	12	4	9		43	19	8	
					585	2,200	Pd-M	5	39	19	15		34	37	9	
			8-9-52		585	2,200	Ud-M	3	28	12	74		43	34	26	
					560	1,800	Ud-F	24	21	70	6	13		47	23	
Columbia River at Juniper Canyon	C-306	Right Shore	5-7-52	Bass, S.M. - Micropterus dolomieu	265	325	Ud-M	-6	63	-19	32		16		37	44
			6-18-52	Carp - Cyprinus carpio	120	30	Juv.		75							166
				Sucker, Coarse Scaled - Catostomus machrocheilus	90	16	Juv.		1,130							915
Columbia River below Corbett, Oregon	C-125	Mid-stream	3-31-53	Carp - Cyprinus carpio	400	900	D-M	16	11	21	46		68	46	19	57
				Sucker - Catostomus macrocheilus	410	900	D-F	14	34	16	33			32		170
					430	1,000	D-F	37	98	310	210			480	1,300	1,300
				Sturgeon - Acipenser transmontanus	460	450	Juv.	-6	8	41[4]	3[2]				91	410
					485	500	Ud-F	100	-1	-20[4]	23[2]	46			62	43
Columbia River at Astoria, Oregon	C-13	Right shore	11-10-52	Codfish - Microgadus proximus	200	80	Juv.	53	72	210	410					240[3]
					210	90	Juv.	61	45	150	280					130[3]
					195	80	Juv.	120	80	180	450					230[3]
				Sculpin - Cottus sp.	100	90	Juv.	0	65		220					10[3]
			3-10-53	Flounder - Platichthys stellatus	152	42	Juv.	44	77	120	180				79	
					120	20	Juv.		84							260[3]
TRIBUTARIES																
Yakima River at Richland Highway Bridge	CY-339	Left shore	5-7-52	Carp - Cyprinus carpio	80	15	Juv.		17							[3]
			7-2-52	Bass - Micropterus salmoides	350	350	Ud-F	0 ± 15	20 ± 8	21 ± 27	50 ± 22	16 ± 13		41 ± 38	38 ± 13	28 ± 29
					300	350	Ud-M	43 ± 28	4 ± 7	66 ± 41	48 ± 26		21 ± 38	-11 ± 43	12 ± 15	44 ± 27
Snake River near the mouth	CS-325		2-6-52	Bass - Micropterus dolomieu	105	18	Juv.		17 ± 8							[3] ± 44
Walla Walla River at Old Highway Crossing	CWw-322		10-29-52	Trout - Salmo gairdnerii	360	450	Pd-F	48 ± 7	30 ± 12	354 ± 52	37 ± 49				65 ± 18	80 ± 24

(1) F = Female; M = Male; Pd = Partly developed; Ud = Undeveloped; D = Developed; Sp = Spent; Juv. = Juvenile
(2) Notochord; (3) Viscera; (4) Bony Plate

APPENDIX "C"

WATER QUALITY STUDIES

ROOSEVELT LAKE - WASHINGTON

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ABSTRACT

A study of the water quality characteristics and biological conditions in Roosevelt Lake was made during the period September 22 to October 1, 1952. Information from this reservoir, a high "multiple purpose" type of impoundment with water depths up to 385 feet, would be expected to give data valuable in predicting effects of future Columbia River impoundments.

Samples of water, plankton, bottom animals and fish were obtained at ten ranges throughout the reservoir to determine existing physical, chamical, bacteriological and biological characteristics. Radiological background information was obtained from some of these samples.

While physical and chemical conditions of the water appear favorable for the support of a mixed aquatic biota, some changes in water quality within the reservoir as a result of the impoundment are indicated. These changes include:

1. An increase in water temperature from the upper to the lower sections of the lake. Little or no thermal stratification was evident at any of the ranges examined.

2. A slight decrease in dissolved oxygen saturation, especially in the deeper waters, although only one area showed a definite oxygen deficiency.

3. An increase in the free CO_2, with a corresponding change in pH values, from the surface to deeper waters.

4. A possible increase in manganese and iron in the deeper waters.

5. A decrease in the suspended materials load from the upper to the lower reservoir.

Bacterial contamination in most parts of the reservoir was at a minimum, although M.P.N. values of 700 per 100 ml. and over were found in the upper part.

Biological conditions were in general very poor. Phytoplankton was extremely limited throughout the reservoir but a buildup of zooplankton was quite noticeable in the lower half. The bottom fauna was quite sparse, consisting only of a few tolerant species, and much different from unimpounded sections of the Columbia River. The large amount of suspended material in the Pend Oreille River appeared detrimental to bottom fauna in and near its mouth. Fish were also limited, the principal population being rough and forage species, with few game fish and little sport fishing.

The low biological productivity is thought to be due principally to:

1. The lack of nutrient materials in the inflow waters which drain infertile mountain regions.

2. The annual deposition of suspended material, especially in the upper reaches of the reservoir.

3. The high ratio of incoming water to reservoir capacity, causing frequent replacement of the contents.

4. The sharp drop-off at the shore line, giving very few areas of shallow water.

5. The large winter and spring drawdowns, which limit aquatic vegetation and bottom fauna production and may affect fish reproduction.

Radioactivity values were all at or near instrument background.

Other studies made in April 1953, at maximum drawdown levels, indicated:

1. Little change in physical and chemical conditions and no appreciable quantities of heavy metals believed to be toxic.

2. Penetration of finely suspended rock flour for a considerable extent into Roosevelt Lake Much of this turbidity reportedly originates at various base metal recovery mills at the Upper Columbia Pend Oreille, and Salmo Rivers.

3. A heavy pulse of the diatom Asterionella sp in the lower reservoir.

4. No bacterial contamination into the lower lake through the earth fill separating Crescent Bay.

GENERAL INFORMATION

The main objective of the Roosevelt Lake studies was to obtain water quality characteristics and biological data on an existing Columbia River impoundment. The data thus obtained will assist in predicting the effects of future impoundments on this river.

Since Roosevelt Lake is a high, "multiple-purpose" type of impoundment the data would indicate one extreme of conditions to be expected in future impoundments. The information from the Bonneville area, a low "run-of-the-river" impoundment, indicates the other extreme of conditions to be expected. All other proposed reservoir projects, at least on the main river, would fall somewhere between these extremes. Several agencies were interested in various phases of this work and the data obtained will be useful to them.

PARTICIPATING AGENCIES

Other agencies participating in the survey were the Washington State Department of Health, Washington State Pollution Control Commission, the U.S. Bureau of Reclamation, U.S. National Park Service, and the Pacific Northwest Drainage Basins Office of the Public Health Service.

The State Department of Health is primarily interested in the sanitary quality of the stream as it may relate to bathing beach and picnic area water quality as well as to water usage by municipalities in the area.

The State Pollution Control Commission and the Pacific Northwest Drainage Basins Office of the Public Health Service are interested from the standpoint of their overall State and Federal pollution control responsibilities. The Bureau of Reclamation is interested in the sanitary quality of the waters from the standpoint of usage by municipalities, both in the reservoir area and at downstream points.

The National Park Service, having jurisdiction over the lake and immediate shore areas for recreational purposes, is interested in sanitary water quality as it may affect bathing beaches and picnic areas, as well as ecological conditions as they may relate to other recreational possibilities such as fishing or hunting.

GENERAL PLAN OF OPERATION

The survey was conducted during the period September 22 to October 1, 1952. Low water stages and maximum water temperatures are normally expected at this season of the year.

Ten sampling ranges were established within the reservoir area. Each one was designated by a mileage index number, which gives the distance in miles from a fixed reference point established by the U.S. Corps of Engineers at the mouth of the Columbia River. The use of this system permits a direct tie-in with studies made in other sections of the Columbia River. Sampling ranges were located from the standpoint of obtaining information on the reservoir as a whole as well as on particular areas of interest to other agencies. Time was not available for a study of individual sources of pollution.

The area covered by the study and the location of sampling ranges are shown in figure C-1. Sampling ranges were established as follows:

CPO-756: Pend Oreille River, approximately 10 miles above the mouth. This was the first easily accessible point above the Consolidated Mining Company's dam, under construction near the mouth of the river. It was expected that the construction would have some effect on the downstream water quality and hence samples below that point would not indicate the natural water quality characteristics of this tributary.

CPO-746: Immediately above the mouth of the Pend Oreille River and below the Consolidated Mining Company's dam. This stream enters the Columbia River above the backwater from Roosevelt Lake and is quite rapid and turbulent at this point.

C-732: At old ferry landing, near center of Northport, Washington. The river current here is quite rapid and not noticeably affected by backwater. All stations below this were well within the backwater areas and there was no noticeable current.

C-703: South of U.S. Highway No. 395 Bridge near Kettle Falls, approximately two miles below the mouth of the Kettle River.

C-694: Two miles below the mouth of the Colville River, near Rickey Point Light.

C-674: Below Gifford Ferry.

C-644: One mile above the mouth of the Spokane River

CSp-644: Spokane River, one mile above the mouth and just above State Highway No. 22 Bridge. This range is within the backwater area.

C-641: Two miles below the mouth of the Spokane River.

C-615: One mile below the mouth of the San Poil River, just west of Republic Ferry. A National Park Service boat ramp and possible swimming area are located on the south shore at this section.

C-597: One mile above Grand Coulee Dam. A National Park Service swimming area and boat ramp are located on the North Shore.

Crescent Bay: A bacteriological sampling point was established near the junction of Crescent Bay with Roosevelt Lake. An earth fill separates these two bodies of water. The untreated domestic sewage from the town of Grand Coulee empties into Crescent Bay and some seepage into the lake was suspected. Since water is pumped from the reservoir a short distance below this dike, the Bureau of Reclamation

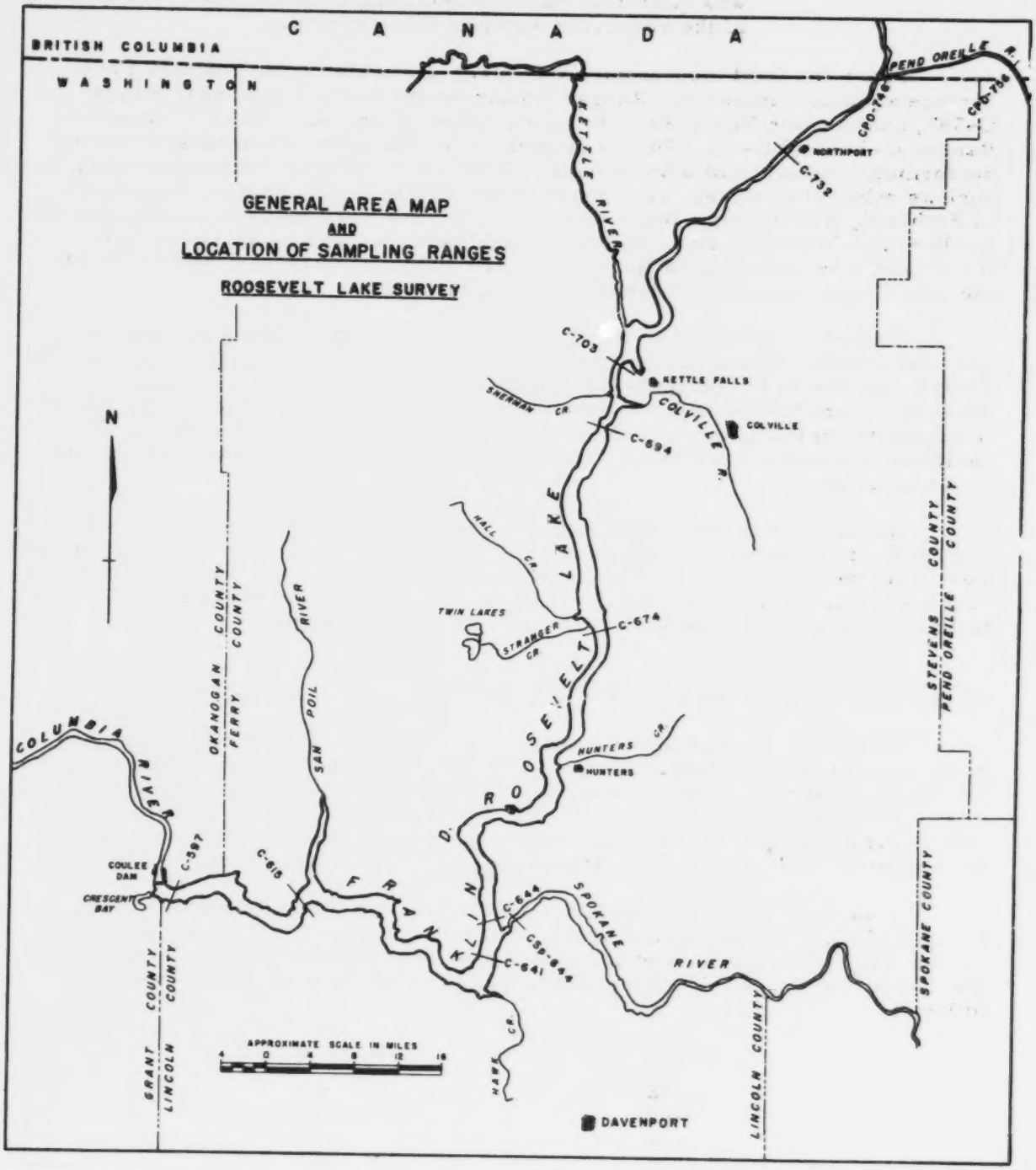
GENERAL AREA MAP
AND
LOCATION OF SAMPLING RANGES
ROOSEVELT LAKE SURVEY
CANADA
BRITISH COLUMBIA
WASHINGTON
PEND OREILLE R.
CPO-746
CPO-736
NORTHPORT
C-732
KETTLE RIVER
C-703
KETTLE FALLS
SHERMAN CR.
COLVILLE R.
COLVILLE
C-694
N
HALL CR.
TWIN LAKES
STRANGER CR.
C-674
ROOSEVELT LAKE
OKANOGAN COUNTY
FERRY COUNTY
SAN POIL RIVER
STEVENS COUNTY
PEND OREILLE COUNTY
HUNTERS CR.
HUNTERS
COLUMBIA RIVER
COULEE DAM
CRESCENT BAY
C-587
C-615
FRANKLIN D.
C-644
CSD-644
C-641
SPOKANE RIVER
HARE CR.
GRANT COUNTY
LINCOLN COUNTY
APPROXIMATE SCALE IN MILES
4 0 4 8 12 16
DAVENPORT
LINCOLN COUNTY
SPOKANE COUNTY

FIGURE C-1

was quite interested in obtaining bacteriological analyses of the reservoir water in this vicinity.

Space for field laboratories was made available by the National Park Service at their Coulee Dam Ranger Station on the north shore, near Range C-597, and at their Kettle Falls Ranger Station, on the east shore between Ranges C-703 and C-694. Simple chemical and biological examinations were performed at these field laboratories. Other more complex determinations, such as mineral analyses, were made in the Public Health Service laboratory at Richland, Washington. Bacteriological analyses were made by the Bureau of Reclamation laboratories in Ephrata, Washington, as well as by personnel of the Washington State Health Department and Pollution Control Commission at the City Health Department laboratories in Spokane.

Personnel assigned to the field study included two biologists and one chemist from the Columbia River Studies Group, and one biologist from the PHS Pacific Northwest Drainage Basins Office for most of the survey. Other personnel from the Columbia River Studies group picked up samples for return to the Richland laboratory. Personnel from the Washington State Health Department transferred the bacteriological samples from the point of collection to the laboratory.

Samples were collected from two portable aluminum boats equipped with outboard motors, the units being transported overland to the various ranges. During the period when one of the motors was inoperative the National Park Service furnished a power launch for collecting some of the samples. Personnel from that agency also assisted materially in locating ranges.

DESCRIPTION OF ROOSEVELT LAKE AND SURROUNDING AREAS

Franklin Delano Roosevelt Lake, the reservoir formed by impoundment of the Columbia River behind Grand Coulee Dam, extends from the Dam to near the Canadian border, a distance of about 150 miles. The lake averages about a mile in width, is over 350 feet at maximum depth, and covers an area of approximately 85,000 acres. There are six hundred miles of shoreline around the reservoir and, when full, it holds nearly 10 million acre-feet of water.

Measured reservoir depths varied from a maximum of about 40 feet, at Range C-732, to a maximum of about 385 feet at Range C-597, near Grand Coulee Dam. The gradient of the lake bottom was gradual between Range C-732 and Range C-597. Maximum recorded depths at the various ranges were as follows:

Range	Depth in Feet
C-732	40
C-703	150
C-694	150
C-674	200
C-644	220
CSp-644	170
C-641	270
C-615	340
C-597	385

Grand Coulee Dam, largest concrete structure in the world, is located at river mileage 596.5, in the northeast part of Washington, 92 miles west and north of Spokane and 240 miles east of Seattle, by highway. This dam, part of a so-called "multiple purpose" project, was built by the Bureau of Reclamation and completed in 1939. It is designed to ultimately irrigate one million acres of semi-arid land in the Columbia Basin and to develop 2-1/2 million kilowatts of electrical power. Some storage capacity is available for flood control purposes.

The area surrounding the lake is sparsely populated, the towns of Grand Coulee, Coulee Dam, Davenport, Colville, Kettle Falls, and Northport being the main centers of population. The extreme lower twenty miles of the reservoir is in semi-arid territory having grasslands and sagebrush cover. The remainder is sparsely to densely forested. The area on the west side of the lake is relatively inaccessible and is occupied mainly by the Colville Indian Reservation and the Colville National Forest. Wheat farming, livestock grazing and lumbering are the principal operations on the east side of the lake. Some mining operations are also carried out. The National Park Service has control of the reservoir and the immediate shoreline areas for development of recreational facilities. Good highways provide relatively easy access to the east side of the lake.

A large portion of the waters come from snows in remote, high mountain regions in Canada, Eastern Washington, Idaho and Western Montana. No provision is made at Grand Coulee Dam for either fish passageways or navigation locks as the height of the structure, 370 feet, precludes its use for these purposes under present knowledge and conditions.

STREAM FLOWS

River flows were low and quite uniform during the survey, the reservoir being about five feet below the normal pool elevation of 1,290 feet above mean sea level. The flows at this time were probably approaching the minimum low values of approximately 25,000 c.f.s. which generally occur in the late fall and winter. The storage capacity of the reservoir is drawn upon during these low flow periods and the reservoir may be drawn down to a maximum of 80 feet before the annual spring run-off period usually occurring in May or June. The normal pool elevation is maintained at all times except during periods of drawdown. Spillways are designed for a maximum capacity of 1,000,000 c.f.s. During high run-off periods surplus water is also pumped into the equalizing basin for irrigation.

Normal flows during the summer are generally adequate for both irrigation and power purposes and there is little change in lake elevation during the summer months. Average annual run-off into the reservoir is just under 80,000,000 acre-feet. The mean annual discharge at the dam is approximately 104,000 c.f.s., with a maximum recorded flow of 638,000 c.f.s. occurring in June 1948.

During the period of this survey, surface velocities in the reservoir were negligible. The only location within the impoundment having any noticeable velocity was at Range C-732.

SURVEY PROCEDURES

Samples of water and aquatic organisms were collected at all ranges and at various depths for the determination of physical, chemical, bacteriological and biological conditions. Later, some of the samples of plankton, juvenile fish and adult fish which had been collected and preserved were examined for alpha and gross beta radioactivity densities. The procedures used for the collection and examination of these samples are described briefly in this section.

Physical and chemical determinations on individual samples included those for temperature, turbidity, dissolved oxygen, alkalinity, pH and free carbon dioxide. Analyses for calcium, magnesium, iron, manganese, zinc, copper, nitrates, sulfates, phosphates, specific conductivity and total solids were made on composite samples.

Biological determinations covered the quantitative estimation of plankton and bottom animal populations and studies of juvenile and adult fish. Bacteriological examinations were limited to determination of the M.P.N. Coliform Index.

COLLECTION OF SAMPLES

The collection of various samples was in accordance with procedures used or adapted for the Public Health Service studies in the Priest Rapids - Paterson Section of the Columbia River. Some modifications were necessary because of the greater water depths.

Water

Samples of water for field determinations of temperature, turbidity, dissolved oxygen, alkalinity, pH and free carbon dioxide were taken with either a 1- or 3-liter Kemmerer sampler at various depths, between the surface and the bottom. Collections were made at quarter points across all of the ranges. Five-gallon composite surface samples were taken at all sections, as well as in deep water near the reservoir bottom at Ranges C-694, C-641, and C-597, for mineral determinations.

Samples for bacteriological examinations were collected near each shore and at quarter points at all ranges. These were taken by filling sterile bottles held immediately below the water surface.

Aquatic Organisms

Composite water samples from the surface and near the bottom were obtained at most of the ranges for quantitative plankton determinations. Other plankton samples were collected from tows made with a standard number 20, silk bolting cloth net (173 meshes per inch) in order to determine the presence and relative abundance of some of the larger plankton organisms, mostly zooplankton.

Quantitative bottom animal collections were made with a 1/4-square foot Ekman dredge at all ranges, between 2 and 6 samples being taken at each section. A few shallow bottom areas at various shore points were examined to

determine the presence and relative abundance of bottom animals.

Juvenile fish were taken near shore areas by seining with a 10-foot 1/4-inch mesh minnow seine. Adult fish collections were taken with gill nets. Overnight bottom sets were made at various depths with 1", 2", and 3" mesh nets. Other information on fish was obtained from the National Park Service, local fisherman and others within the area, as well as from previously published reports.

LABORATORY METHODS

The laboratory methods used for many of the routine examinations were taken from various standard sources. Other procedures were those developed for the studies in the Priest Rapids - Paterson Section.

Chemical and Physical Examinations

Analytical techniques used for most of the chemical and physical examinations were those given in "Standard Methods for the Examination of Water and Sewage" 9th Edition, American Public Health Association, with some modifications to fit field conditions.

Surface water temperatures were read from a regular Centigrade thermometer. It had been planned to take depth temperature readings with a Foxboro Portable Electric Thermometer or a Negretti-Zambra reversing thermometer. However, both of these instruments were found to be inoperative and could not be repaired in time for the survey. Consequently depth temperatures were taken immediately on water samples brought up from various depths with the 3-liter Kemmerer sampler. It was felt that readings would be quite accurate, as the time involved in taking samples was very short. The temperature differential from surface to bottom is generally small, as indicated by Bureau of Reclamation and Fish and Wildlife Service data.

Surface turbidity readings were made where possible with a USGS Standard Water Turbidity Scale. Analyses for dissolved oxygen, free CO_2, pH and alkalinity were done in the field with a portable chemical kit. The pH values were determined with a Hellige colorimetric comparator disk. All other chemical determinations were made at the Richland laboratory.

Methods for the determination of copper and zinc were taken from "Colorimetric Determination of Traces of Metals", by E. P. Sandell (Interscience Publishers Inc., 1950). Specific conductances were determined with an Industrial Instrument Company Solu Bridge, Model RD-R-4.

Bacteriological Examinations

Examinations of bacteriological samples were made by other agencies, as previously mentioned. These tests were confined to the determination of the M.P.N. Coliform Index as outlined in "Standard Methods, IX".

Biological Examinations

Procedures for the collection and examination of aquatic organisms generally followed those given in "Limnological Methods", by P.S. Welch

(The Blakiston Company, 1948).

For plankton determinations six-liter water samples for count and 10-liter samples for weight were centrifuged in a Foerst Centrifuge set up at the temporary field laboratory. The organisms were removed and preserved in 10% formalin for future study. Later, in the Richland laboratory, these were identified and numerical counts made in a Sedgewick-Rafter counting cell. Weights were determined after drying at 60°C for 24 hours. Organic content was found by ashing in a muffle furnace at 600°C for 30 minutes.

Most of the organisms found were of the single-cell type. However, whether a cell, colony, or filament each individual organism was counted. Most of the colonies of diatoms were broken into individual cells by centrifuging. In general, the Asterionella sp remained intact and several cells were present in each organism.

Bottom organism samples were sorted, identified to order, counted and weighed after blotting for 1 minute to remove surface moisture. Juvenile fish were sorted, identified and relative abundance of the various species noted. Data recorded for adult fish included the length, weight and species of each specimen caught.

Radiological Examinations

It had not been planned originally to obtain radiological data in the Roosevelt Lake study. This lake was above known possible sources of radioactive effluent discharges and it was felt that the only data that could be obtained here would be at background activity levels, near or below minimum detectable limits. Later it was decided to obtain data on biological samples which had been collected and preserved during the study.

Samples of plankton, juvenile fish and individual parts of adult fish were prepared by digesting in nitric acid, ashing and plating the residue on 1" stainless steel planchets. Gross beta activity densities were determined by counting in a Geiger-Mueller End-Window tube counter and applying necessary correction factors. Some of these samples were also analyzed by another method developed at the Sanitary Engineering Center Laboratories at Cincinnati, Ohio, and counted in internal flow counters for alpha and gross beta activity densities.

DISCUSSION OF RESULTS

The total number of samples collected and analyses made are given in table C-1. The results of the laboratory examinations are discussed below.

Table C-1 - SUMMARY OF SAMPLING AND LABORATORY LOAD

Examination	No. of Samples	Determinations
Bacteriological	50	50
Chemical and Physical		
Routine	127	912
Mineral Analyses	13	143
Biological		
Bottom Organisms	14	14
Plankton	17	17
Radiological		
Biological	52	79

BACTERIOLOGICAL EXAMINATIONS

Results of the bacteriological analyses are presented in table C-2. The M.P.N. Coliform Index was quite low for most of the samples examined. This indicates water relatively free of domestic pollution throughout the reservoir area. The low counts found in the lake near the Crescent Bay entrance show that during this survey there was little or no penetration of domestic pollution through the earth fill separating this area. Results in the vicinity of the National Park Service recreational areas at Ranges C-597, C-615, CSp-644 and C-703 were all uniformly quite low. The highest values within the lake occurred at Range C-732, maximum M.P.N. values of 700, or over, per 100 milliliters being found near both shores there. This indicates some domestic pollution in the vicinity of Northport or further upstream. Values in the Pend Oreille River were also higher than in the major portion of Roosevelt Lake proper.

While the values appear uniformly low at this season, additional samples should be taken in the summer months, during periods of maximum recreational use of the lake, in order to obtain a better evaluation from this standpoint. Samples should also be taken adjacent to Crescent Bay during periods of maximum drawdown in order to detect any possible seepage.

Table C-2 - RESULTS OF BACTERIOLOGICAL ANALYSES

Sampling Range	Distance from South or E. Shore	Date (1952)	MPN per 100 ml.	Sampling Range	Distance from South or E. Shore	Date (1952)	MPN per 100 ml.
CPO-746	N. Shore	9/29	240	C-644	100'	9/24	< 45
			62		1/4		< 45
					1/2		< 45
	S. Shore		240		3/4		60
					W.Shore		< 45
C-732	100'	9/29	700	CSp-644	100'	9/24	< 45
	1/4		130		1/2		< 45
	1/2		130		N. Shore		60
	3/4		240				
	W.Shore		>700	C-641	100'	9/24	< 45
					1/4		46
C-703	100'	9/26	60		1/2		< 45
	1/4		< 45		3/4		< 45
	1/2		< 45		W.Shore		< 45
	3/4		60				
	W.Shore		< 45	C-615	100'	9/23	< 45
					1/4		< 45
C-694	100'	9/26	< 45		1/2		< 45
	1/4		< 45		3/4		60
	1/2		< 45		N.Shore		< 45
	3/4		< 45				
	W.Shore		60	C-597	100'	9/23	< 45
					1/4		< 45
C-674	100'	9/26	< 45		1/2		< 45
	1/4		< 45		3/4		< 45
	1/2		< 45		N.Shore		< 45
	3/4		< 45				
	W.Shore		< 45	Crescent Bay	N.End-Dike	9/23	< 45
					Mid-Dike		< 45
					S.End-Dike		< 45

PHYSICAL AND CHEMICAL EXAMINATIONS

Results of physical and chemical determinations are given in tables C-3 and C-4. The individual results are discussed below.

Turbidity

Turbidity readings at all locations within the lake were less than 7 p.p.m., the minimum value detectable with the USGS turbidity scale. Water in the middle and lower reservoir appeared extremely clear and colorless, bottom areas being visible in depths of about 15 feet. The upper lake, Range C-732, was also clear, though some suspended material could be observed. The mouth of the Spokane River was clear but with a greenish cast, most probably due to the presence of plankton algae. All of the smaller tributaries examined were also quite clear.

The Pend Oreille River on the other hand was quite turbid and gray in color. Large quantities of a material resembling rock powder were suspended in the water. The bottom areas and rocks were completely covered with a flour-like gray blanket. The junction of this stream with the clear waters of the Columbia River was quite marked, and the line of demarkation could be followed visibly for a considerable distance downstream. When this condition was first noted at the mouth of this tributary it appeared to be due to the drilling and construction operations on the dam being built just above the mouth. However, the same condition was found to prevail at Range CPO-756, above the construction site and about 10 miles from the mouth. It has been reported that several base metal recovery mills on the Pend Oreille and other streams are discharging slimes which are the cause of much of this turbidity.

Temperature

In a large deep impoundment of this type it was suspected that some thermal stratification would be found. However, a careful examination throughout the lake showed no temperature stratification at any of the ranges established during this survey, at least at this season of the year. The largest temperature difference between surface and bottom was found at the 350-foot depth near Grand Coulee Dam. This differential reached a maximum of only 2°C at Range C-597, and generally varied from 0.5°C to 1°C at the other ranges, the temperatures being slightly lower in the deeper water than on the surface.

Seasonal temperature curves, obtained from the Bureau of Reclamation, show that little or no temperature stratification has been present in the reservoir during the last six years. The maximum temperature difference from surface to bottom has been from about 1 to 7°C, the decrease being rather uniform from top to bottom.

A typical seasonal temperature curve from the lake, furnished by the Bureau of Reclamation, is shown in figure C-2. Maximum surface temperatures during 1951 were approximately 21°C and occurred in early September. Maximum bottom temperatures, occurring about a month later, were approximately 18°C. Maximum and minimum surface and depth temperatures occurring from 1943 to 1951, inclusive, are shown in table C-5. From more detailed records it appears that a fairly definite temperature stratification did exist for

Table C-3 - SUMMARY OF ANALYTICAL RESULTS

Sampling Range	Distance from South or E. Shore	Depth Ft.	Date (1952)	Turb. ppm	Temp °C	D.O. ppm	Free CO_2 ppm	pH	Alkalinity ppm	
									M.O.	Phen
CPO-760	N. Shore	1	9/29	19	17.0	8.6	0	7.9	80	0
CPO-746	N. Shore	1	9/29	19	17.5	8.8	0	7.9	80	0
C-732	1/4	1	9/29	<7	16.5	8.4	0	7.6	58	0
		10			16.5	8.4	0	7.6	60	0
		25			16.5	8.3	0	7.5	60	0
	1/2	1	9/29	<7	16.5	8.4	0	7.7	60	0
		10			16.5	8.4	0	7.7	60	0
		25			16.5	8.4	0	7.7	60	0
		30			16.0	8.4	0	7.7	60	0
	3/4	1	9/29	<7	16.5	8.4	0	7.7	60	0
		10			16.5	8.4	0	7.7	60	0
		25			16.5	8.4	0	7.7	60	0
		30			16.5	8.4	0	7.7	60	0
		40			16.0	8.4	0	7.7	60	0
C-703	1/4	1	9/27	<7	17.0	8.2	0.5	7.8	61	0
		10			17.0	8.2	0.5	7.6	60	0
		25			17.0	8.0	0.5	7.6	60	0
		50			17.0	8.0	0.5	7.6	60	0
		100			17.0	8.0	1.0	7.6	61	0
		150			17.0	8.1	1.0	7.6	62	0
	1/2	1	9/27	<7	17.0	8.2	1.0	7.7	62	0
		50			17.0	8.1	1.0	7.6	61	0
		125			17.0	8.2	1.0	7.6	62	0
	3/4	1	9/27	<7	17.0	8.3	1.0	7.7	63	0
		25			17.0	8.2	1.0	7.7	62	0
		50			17.0	8.2	1.0	7.6	63	0
		100			17.0	8.0	1.0	7.6	61	0
		150			17.0	8.1	1.0	7.6	61	0
C-694	1/4	1	9/26	<7	18.0	8.2	0	8.2	65	0
		10			18.0	8.2	0	8.2	62	0
		25			18.0	8.2	0	8.2	62	0
		50			18.0	8.1	1.0	8.1	60	0
		100			17.5	8.0	1.0	7.9	62	0
		150			17.0	7.5	1.0	7.9	61	0
	1/2	1	9/26	<7	18.0	8.2	0	8.1	62	0
		10			17.5	8.3	0.5	7.9	61	0
		25			17.0	8.2	0.5	7.9	61	0

Table C-3 - SUMMARY OF ANALYTICAL RESULTS (Continued)

Sampling Range	Distance from South or E. Shore	Depth Ft.	Date (1952)	Turb. ppm	Temp ppm	D.O. ppm	Free CO_2 ppm	pH	Alkalinity ppm	
									M.O.	Phen
C-694 (cont.)	1/2	50	9/26		17.5	8.2	0	7.9	63	0
		100			17.0	8.0	0.5	7.9	62	0
		150			17.0	7.4	1.0	7.7	62	0
	3/4	1	9/26	<7	17.5	8.2	0.5	8.1	62	0
		25			17.5	8.2	0.5	8.1	62	0
		50			17.5	8.1	0.5	8.0	61	0
		100			17.0	8.0	0.5	7.9	60	0
C-674	1/4	1	9/28	<7	18.0	8.3	0	8.2	59	0
		10			18.0	8.3	0	8.2	57	0
		50			17.5	8.1	0	8.0	57	0
	1/2	1	9/28	<7	18.0	8.4	0	8.2	59	0
		50			17.5	8.3	0	8.0	57	0
		100			17.0	8.0	0.5	7.8	58	0
		200			17.0	7.7	1.0	7.7	58	0
	3/4	1	9/28	<7	18.0	8.3	0	8.2	60	0
		50			17.5	8.2	0.5	8.0	58	0
		130			17.0	8.0	0.5	7.8	58	0
C-644	1/4	1	9/28	<7	19.0	8.7	0	8.0	55	0
		100			18.0	8.3	1.5	7.4	60	0
		200			17.5	8.3	2.0	7.4	65	0
	1/2	1	9/28	<7	19.0	8.7	0	8.0	58	0
		10			19.0	8.6	0	8.0	58	0
		25			19.0	8.5	0	8.1	58	0
		50			18.5	8.3	0	8.0	59	0
		100			18.5	8.0	1.0	7.9		0
		200			17.5	8.0	1.5	7.8	58	0
	3/4	1	9/28	<7	19.0	8.5	0	8.0	58	0
		50			18.5	8.4	0	8.0	58	0
CSp-644	1/2	1	9/30	<7	19.0	8.4	0	8.0	58	0
		10			19.0	8.1	0	7.9	58	0
		25			19.0	8.0	0	8.0	57	0
		50			19.0	8.0	1.0	7.9	55	0
		100			18.5	5.4	3.5	7.3	65	0
		150			18.0	3.1	6.0	7.2	85	0
C-641	1/4	1	9/24	<7	19.8	8.0	0		58	0
		50			18.5	7.9	0		58	0

Table C-3 - SUMMARY OF ANALYTICAL RESULTS (Continued)

Sampling Range	Distance from South or E. Shore	Depth Ft.	Date (1952)	Turb ppm	Temp °C	D.O. ppm	Free CO_2 ppm	pH	Alkalinity ppm	
									M.O.	Phen
C-641 (cont.)	1/4	100	9/24		18.0	7.5	1.0		62	0
		150			18.0	7.4	1.0		59	0
	1/2	1	9/24	<7	19.8	8.0	0		58	0
		10			19.3	8.0	0		57	0
		25			19.3	8.0	0		59	0
		50			19.0	8.0	0		59	0
		100			18.5	7.6	0.5		58	0
		200			18.0	7.4	1.0		59	0
		250			18.0	7.0	1.5		60	0
	3/4	1	9/24	<7	19.8	8.0	0		60	0
		50			19.0	7.9	0		59	0
C-615	1/4	1	9/23	<7	19.5	7.3	0		59	0
		100			19.0	7.2	0.5		57	0
		165			18.5	7.2	1.5		57	0
	1/2	1	9/23	<7	19.3	8.2	0		59	0
		10			19.0	8.0	0		60	0
		25			19.0	8.3	0		63	0
		50			19.0	7.9	0		65	0
		100			19.0	8.1	0		57	0
		200			18.0	7.5	1.0		58	0
	3/4	1	9/23	<7	19.3	8.1	0		58	0
		10			19.0	8.1	0		59	0
		25			19.0	8.2	0		59	0
		50			19.0	8.2	0		59	0
		100			18.5	7.3	0.5		58	0
		200			18.0	7.4	1.0		58	0
		340			18.0	6.7	2.0		58	0
C-597	1/4	1	9/25	<7	20.0	7.9	0	8.2	60	0
		10			20.0	8.0	0	8.2	60	0
		25			20.0	8.0	0	8.2	60	0
		50			19.5	8.0	0	8.2	59	0
		100			19.0	8.0	0	8.2	59	0
		200			19.0	7.3	2.0	7.8	60	0
		350			18.0	6.3	4.0	7.4	58	0
	1/2	1	9/23	<7	20.0	7.9	0	8.2	60	0
		50			19.8	8.0	0	8.2	60	0
		100			19.5	8.0	0	8.3	59	0
		200			19.0	7.2	2.0	7.6	58	0
	3/4	1	9/25	<7	20.0	7.9	0	8.2	59	0
		100			19.5	7.9	0	8.4	59	2
		150			19.0	7.3	0.5	7.8	59	0

Table C-4 - RESULTS OF MINERAL ANALYSES ON RIVER WATER SAMPLES

Sampling Range	Depth Feet	Date (1952)	Ca	Mg	Fe	Mn	Zn	Cu	SO_4	PO_4	NO_3	Total Solids	Spec. Cond. µmhos per cm
			Concentration - Parts per million										
CPO-760	1	9/30	26	8.0	0.19	0.025	0	0.100	14	0.04	0.08	150	160
C-732	1	9/29	20	6.0	0.13	0.010	0	0.009	20	0.09	0.13	110	140
C-703	1	9/26	21	6.0	0.07	0.010	0	0.013	16	0.12	0.17	110	150
C-694	1	9/26	21	7.0	0.07	0.010	0	0.024	16	0.10	0.09	110	150
	100	9/26	21	6.0	0.08	0.010	0	0.030	15	0.09	0.09	110	140
C-674	1	9/28	20	7.0	0.07	0.010	0	0.008	15	0.04	0.13	110	140
C-644	1	9/24	19	4.7	0.09	0.010	0	0.004	12	0.04	0.25	66	130
CSp-644	1	9/30	18	6.0	0.06	0.010	0	0.005	12	0.03	0.07	100	130
C-641	1	9/24	19	4.8	0.05	0.010	0	0.002	11	0.03	0.07	63	130
	250	9/24	19	4.3	0.14	0.020	0	0.010	12	0.07	0.10	57	140
C-615	1	9/23	18	5.5	0.06	0.010	0	0.002	10	0.04	0.00	40	130
C-597	1	9/23	21	4.1	0.08	0.010	0	0.033	11	0.01	0.12	51	120
	350	9/23	19	5.0	0.14	0.020	0	0.010	10	0.06	0.16	54	130

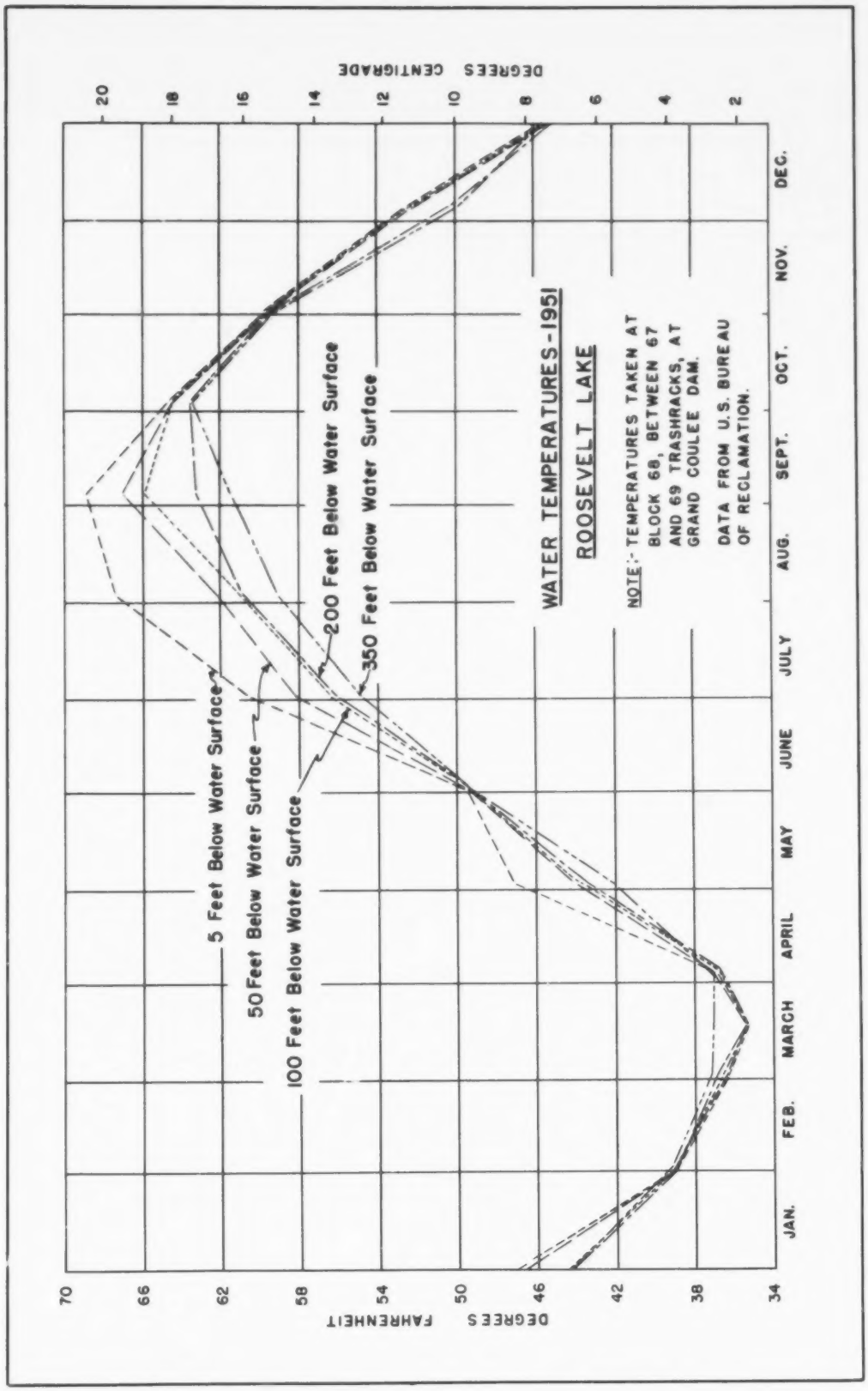
WATER TEMPERATURES-1951
ROOSEVELT LAKE
NOTE:- TEMPERATURES TAKEN AT BLOCK 68, BETWEEN 67 AND 69 TRASHRACKS, AT GRAND COULEE DAM.
DATA FROM U.S. BUREAU OF RECLAMATION.
5 Feet Below Water Surface
50 Feet Below Water Surface
100 Feet Below Water Surface
200 Feet Below Water Surface
350 Feet Below Water Surface
DEGREES FAHRENHEIT
70
66
62
58
54
50
46
42
38
34
DEGREES CENTIGRADE
20
18
16
14
12
10
8
6
4
2
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.

FIGURE C-2

Table C-5 - ANNUAL MAXIMUM AND MINIMUM TEMPERATURES - ROOSEVELT LAKE NEAR GRAND COULEE DAM

Year	Depth in Feet	Maximum		Minimum	
		°C	Date	°C	Date
1943	5	20.6	Aug. 1	3.1	Mar. 15
	350	13.9	Nov. 15	3.1	Mar. 15
1944	5	21.7	Aug. 1	3.3	Mar. 15
	350	9.4	Jan. 1	3.3	Mar. 15
1945	5	19.7	Sept. 1	4.4	Apr. 1
	350	17.0	Dec. 1	4.4	Apr. 1
1946	5	19.4	Sept. 1	3.9	Mar. 15
	350	14.4	Nov. 1	3.9	Mar. 15
1947	5	19.4	Sept. 1	2.2	Mar. 1
	350	15.5	Oct. 1	3.3	Mar. 15
1948	5	21.4	Aug. 1	3.1	Mar. 15
	350	15.3	Sept. 1	3.1	Mar. 15
1949	5	22.8	Sept. 1	0.8	Feb. 1
	350	15.6	Oct. 1	2.8	Apr. 1
1950	5	20.6	Sept. 1	1.7	Mar. 15
	350	16.1	Oct. 1	2.2	Apr. 1
1951	5	20.4	Sept. 1	1.7	Mar. 15
	350	17.5	Oct. 1	2.8	Apr. 1

(Data from U.S. Bureau of Reclamation)

the first few years after the lake was filled. The degree of stratification decreased until 1946. Since then it has followed a pattern similar to that shown in figure C-2.

During this survey there was an increase of 3.5°C in surface water temperatures from Range C-732 (16.5°C) to Range C-597 (20°C). The increase was gradual throughout the impoundment. Results indicate either a warming within the reservoir or the entrance of colder tributary waters, which had not yet displaced the warmer water in the lower end of the lake. This could not be determined definitely without a temperature study at other seasons of the year, preferably when incoming tributary waters are at maximum summer temperatures.

The major cause for the lack of thermal stratification lies in the large flows entering the reservoir. Although the lake has a capacity of 10 million acre-feet, the annual average discharge is 80 million acre-feet, or enough to fill the lake 8 times within one year. The maximum discharge on record, in June 1948, was sufficient to fill the reservoir to capacity in 4 days. The large flows probably preclude any degree of either thermal or chemical stratification.

Dissolved Oxygen

Oxygen conditions were reasonably high and quite favorable for aquatic life throughout the entire body of the lake, both at the surface and in deep waters. Values ranged from a maximum of 8.8 p.p.m. at the surface to a minimum of 6.3 p.p.m. in the deepest portions near the dam. Values of 8 p.p.m. or more were usually found in waters less than 100 feet deep. The only areas sampled and found deficient in oxygen were in the Spokane River, where oxygen values as low as 3.1 p.p.m. were obtained near the bottom in waters 150 feet deep. Even in this area values for waters less than 100 feet in depth were fairly high.

In general, oxygen values throughout the lake were slightly below saturation. From the surface to 100 feet, results varied from 85 to 95% of saturation; between 100 and 250 feet, from 75 to 85%; and between 250 feet and the deepest portions, from 65 to 75%. The deepest water sampled in the Spokane River was only 30 to 35% of saturation.

pH, Alkalinity, and Free CO_2

The pH values of surface samples ranged from 7.6 to 8.2, the lower results being found in the upstream section. There was a decrease in pH from the surface to the bottom due to the buildup of free CO_2 in the deeper waters. The maximum change in pH was found in the Spokane River (Range CSp-644), the values decreasing from 8.0 at the surface to 7.2 near the bottom. The same spread was found at Range C-597, values decreasing from 8.2 near the surface to 7.4 near the bottom.

Correspondingly, free CO_2 values ranged from 0 at the surface to a maximum of 6.0 p.p.m. at the 150-foot depth in the Spokane River (Range CSp-644). Near Grand Coulee Dam the variation was from 0 at the surface to 4 p.p.m. at 350 feet.

Methyl orange alkalinity generally ranged from 55 to 65 p.p.m. (as $CaCO_3$). No phenolphthalein alkalinity was found in any of the samples taken. The results were quite uniform at all sections, both at the surface and in the deep waters. A value of 80 p.p.m. was found in the Pend Oreille River, well above the backwater from Roosevelt Lake.

Mineral Analyses

The values for mineral analyses, given in Table C-4, do not indicate any detrimental condition existing in the lake. All of the results are within limits considered satisfactory for aquatic life. Values for iron, manganese, copper, and total solids are much higher in the Pend Oreille River than at any of the ranges within the lake. Total solids show a wide decrease from a high of 110 p.p.m. in the upper reservoir to a low of 40 to 50 p.p.m. at the lower ranges, with a corresponding decrease in specific conductance. Sulfates also decrease from 20 to 10 p.p.m. from the upper to lower reaches. There appeared to be a slight increase of iron and manganese in the deeper waters. Other mineral characteristics showed some variation between ranges but no definite trends.

For the reservoir, results of mineral analyses (in parts per million) varied between: 18 and 21 for calcium; 4.1 and 7.0 for magnesium; 0.05 and 0.14 for iron; 0.01 and 0.02 for manganese; 0.002 and 0.033 for copper; 10 and 20 for sulfates; 0.01 and 0.12 for phosphates; 0.00 and 0.25 for nitrates; and 40 to 110 for total solids. Results for zinc were 0 p.p.m., while specific conductance values ranged from 120 to 150 micromhos per centimeter.

While the physical and chemical conditions within Roosevelt Lake appear favorable for the support of a good mixed aquatic fauna there is evidence of some changes in water quality characteristics, as has already been pointed out. The more important indications are that:

1. Although there is no evident thermal stratification within the lake, there appears to be a considerable warm-up of water from the upper to the lower parts of the impoundment. This should be studied more thoroughly over a longer period as the increased water temperatures may have considerable effect on the aquatic life in the river below the reservoir.

2. There is a minor decrease in the dissolved oxygen content, a slight build-up of free CO_2., and some change in the pH between the surface and the bottom.

3. A decrease in the suspended material load, as well as total solids, occurs between the upper and lower sections.

4. A possible increase in iron and manganese occurs in the deeper lake waters.

BIOLOGICAL EXAMINATIONS

Physical and chemical conditions at all ranges within the lake area were

favorable for the support of a good mixed aquatic biota, with the exception of the low oxygen content in the deeper areas of the Spokane River.

Plankton

Because of extreme fluctuations of plankton organisms at different seasons and under different water conditions, a study of the plankton at any one season can give only an approximate indication of the productivity of a body of water. It was surprising to note the relatively extreme scarcity of phytoplankton throughout the lake at a season of the year and under water conditions normally favorable to such organisms. Table C-6 shows the number of organisms present and the weight of plankton and organic material at the various ranges.

Phytoplankton were extremely limited at the upper ranges, with only a slight increase toward the lower part of the lake. The diatom Fragilaria sp was the predominant form in most of the samples. At several of the ranges near the entrance of tributary streams fair numbers of single-celled green algal forms were present. Samples from the Spokane River, Range CSp-644, contained much larger numbers of phytoplankton, consisting mostly of the diatom Cyclotella sp, a form found abundantly in some of the tributary streams in the Priest Rapids - Paterson Section of the Columbia River. Many other diatoms as well as some green and blue-green algal forms were present at this range. The numbers of phytoplankton in the lake were generally lower than had been found in the Priest Rapids - Paterson Section.

Zooplankton, consisting of protozoans, rotifers, and crustaceans, were noticeably more abundant in Roosevelt Lake than in the lower sections of the Columbia River. Large swarms of micro-crustaceans, both cladocerans and copepods, were observed in lower parts of the lake, from Range C-644 to Grand Coulee Dam. These organisms were quite plentiful near the shores and large numbers could readily be collected in tow nets. Their true number is probably not shown in the quantitative results, as composite samples were taken at 1/4, 1/2, and 3/4 points and would not include the large numbers observed in shore areas.

An examination of the plankton tows taken at the various ranges, while not quantitative, does give an indication of relative numbers of the various organisms of this type. A sample from Range C-732 shows an extremely sparse population, consisting almost entirely of Fragilaria. At Range C-703, larger numbers of diatoms were present along with a few single-celled green algae and a few protozoans. No crustaceans were observed. At Range C-674, Fragilaria was the predominant photoplankton form. A fair number of crustaceans, mostly copepods, along with a few protozoans and rotifers were also present. At Range C-644 Fragilaria and some green algal forms were fairly abundant and copepods were numerous. A few protozoans and rotifers were also found. In the Spokane River, diatoms and green algae were quite abundant and practically no zooplankton forms were present. At Ranges C-615 and C-597, crustaceans, mostly cladocerans, were very abundant, making up by far the largest proportion of the plankton. Fragilaria, a few green algae, rotifers and protozoans were also collected.

In general, plankton samples taken in deeper water contained fewer

Table C-6 - PLANKTON - COLUMBIA RIVER - ROOSEVELT LAKE SURVEY

SAMPLING DATA				Plankton Weight		Plankton Count - Average Number of Organisms																					
						Per Milliliter																Per 200 Milliliters					
Sampling Range	Location of Sample	Depth - Feet	Date of Sample (1952)	Wet Weight per Liter Milligrams	Organic Matter per Liter Milligrams	BACILLARIOPHYCEAE - TOTAL	Asterionella sp	Cyclotella sp	Diatoma sp	Fragilaria sp	Gomphonema sp	Melosira sp	Navicula sp	Synedra sp	Tabellaria sp	CHLOROPHYCEAE - TOTAL	Ankistrodesmus sp	Pandorina sp	Scenedesmus sp	MYXOPHYCEAE - TOTAL	Oscillatoria sp	PIGMENTED FLAGELLATES - TOTAL	PROTOZOA - TOTAL	CRUSTACEA - TOTAL	Copepoda	ROTIFERA - TOTAL	MISCELLANEOUS	TOTAL ORGANISMS PER MILLILITER
CPO-760	N.Shore	0	9/29			16	2			8			1	1	3	1							1			1	1	17
C-732	Cross-section	0	9/29			10	1		1	4				1	1	1	1						2			1	1	11
C-703	"	0	9/27			13	3			5		1		1	2	5		3					11				7	18
C-694	"	0	9/26	1.09	0.31	21	5			11		1	1		2	45	1	36					86			2	6	66
	Depth	100				18	3			10			1		4	1							2	1	1		1	20
C-674	Cross-section	0	9/28			686				17			669			17	9		6				1	1	1	1	1	703
C-644	"	0	9/24			72				69		1		1		50	1						4	8	8	14	6	122
CSp-644	"	0	9/24			2,091	49	1,665	7	10	12	47	52	10		54	7		22	5	5	59	3			1	4	2,209
C-641	"	0	9/24	2.50	0.52	19	1			17						2	1						17	5	5	3	1	21
	Depth	200				16		1		11			3			2			1	1			3	3	3	2	1	19
C-615	Cross-section	0	9/23			63				61				1			1						64	10	10	6	1	64
	Depth	100				50				48			1			1							15	2		3	2	51
C-597	Cross-section	0	9/25	1.14	0.35	33	1			29			1	1		2	1						69	7	7	15		35
	Depth	300				6	1	1		3		1				1			1				4	2	2	1		7

organisms than those from the surface. Nevertheless some organisms, both phytoplankton and zooplankton, were found to be present at all depths down to 350 feet, the numbers decreasing as the depth increased.

The plankton would be considered extremely poor, especially in the upper sections of the lake. It would be quite important to study the plankton at other seasons of the year to see if this condition prevailed at all times. One of the reasons for a study of the plankton in this lake was to determine whether build-ups, which could affect water treatment plants in downstream sections of the Columbia River, might occur. At this season there was definitely no great build-up of phytoplankton forms, although zooplankton was relatively abundant in the lower lake. Large increases in the diatom Asterionella sp were observed in the lower Columbia River in May and June during the years 1950, 1951, and 1952. A study of the plankton in the lake during or prior to this period would be quite important to determine if a build-up here may be related to the downstream pulses. Studies at other seasons may also be important in determining the lake productivity.

Bottom Fauna

The numbers and weights of bottom animals in the quantitative collections made at the various ranges are shown in table C-7.

Bottom animal populations were quite poor throughout the lake, practically the entire fauna consisting of two organisms, Oligochaete worms and Chironomid larvae. The variation in numbers and weights was very great, even at the same station, the numbers ranging from 26 to 840 per square foot. This variation was, no doubt, caused by the differences in bottom conditions. Where large quantities of silt were brought up with the samples there were a great many more organisms present than when fine and coarse sand was the only bottom material.

No definite relationship between bottom fauna in upper and lower areas of the lake could be established as fairly rich and poor samples were obtained in the same areas. Bottom fauna did appear just as abundant, if not more so, in the deeper waters as in the shallower regions. A visual examination of shallow shore areas (or littoral zones) did not disclose the presence of any more, if as many, animals as were present in the deep water. The winter drawdown of 50 to 80 feet is probably responsible for the scarcity of animals in the littoral zone. Bottom animals are normally most abundant in the shallow areas, but the large annual drawdowns would tend to destroy these and not give them a chance to become well-established.

Observed physical conditions throughout the lake are not too favorable for the development of a rich bottom fauna. Fine and coarse sand covers a major portion of the lake bed, but there are some areas, mostly in coves and near the shoreline, which have fair silt deposits. Much of the bottom is covered with a layer of debris consisting mostly of wood fibers. The large amounts of water containing suspended material which flows into and through this reservoir during the spring floods probably causes an annual deposition of sand, particularly in the upper lake. This would have a smothering effect on bottom animals and tend to discourage their establishment.

Table C-7 - BOTTOM FAUNA, COLUMBIA RIVER

SAMPLING DATA					ORGANISMS						
Sampling Range	Distance from South or East Shores	Number of Samples @ Depth Taken	Date of Sample (1952)	Size of Sample and Method of Collection		Oligochaetae (Aquatic Earthworms)	Diptera: Chironomidae (Midgefly larvae)	Tupilidae: (Cranefly larvae)	Trichoptera: (Caddisfly larvae)	TOTAL ORGANISMS	TOTAL PER SQUARE FOOT
C-732	3/4	1 @ 12'	9/29	0.5 Sq.Ft. Ekman	Number		13			13	26
					Weight		.01			.01	.02
C-703	1/4	1 @ 80'	9/28	0.25 Sq.Ft. Ekman	Number	30				30	120
					Weight	.09				.09	.36
C-694	1/4	1 @ 90'	9/26	0.5 Sq.Ft. Ekman	Number	97	9			106	212
					Weight	.15	.02			.17	.34
	3/4	1 @ 100'		"	Number	420				420	840
					Weight	1.28				1.28	2.56
C-674	1/4	1 @ 70'	9/28	"	Number		10	2	1	13	26
					Weight		.01			.01	.02
	3/4	1 @ 170'		"	Number	25	11			36	72
					Weight	.08	.03			.11	.22
CSp-644	1/2	1 @ 110'	9/30	"	Number	64				64	128
					Weight	.05				.05	.10
C-641	1/4	1 @ 85'	9/30	"	Number		12			12	24
					Weight		.01			.01	.02
	1/2	1 @ 270'		"	Number	215	59			274	548
					Weight	.58	.10			.68	1.36
	3/4	1 @ 150'		"	Number	9	48			57	114
					Weight	.02	.07			.09	.18
C-615	1/4	1 @ 165'	9/23	"	Number	25	9			25	50
					Weight	.07	.02			.07	.14
	0	1 @ 90'		"	Number	2	12			14	28
					Weight		.02			.02	.04
C-597	1/4	1 @ 385'	10/1	"	Number	43	36			79	158
					Weight	.15	.06			.21	.42
	3/4	1 @ 115'		"	Number	1	37			38	76
					Weight		.05			.05	.10

The bottom fauna population in Roosevelt Lake is entirely different from the populations generally occurring in the Columbia River. The more abundant forms found in other parts of the stream, mayfly and stonefly nymphs, caddis larvae and mollusks, were not found to any extent in the lake.

The scarcity of bottom animals and the limitation of those present to the quite tolerant forms, the scarcity of mollusks, the very poor phytoplankton flora, and the scarcity of zooplankton in the upper reservoir would indicate that conditions unfavorable to the development of these organisms must be present at times. While no detrimental chemical conditions were found during this survey, it is felt that this problem should be further investigated.

As most of the waters entering the reservoir originate in areas of extensive mining operations, toxicity from heavy metals, such as copper, lead, or zinc, could certainly be possible. Bottom organisms would probably be the first affected by pollution of this kind. The large amounts of suspended material in the Pend Oreille River would be expected to be detrimental to aquatic life in that stream.

Fish

Juvenile fish collections were limited to Ranges C-694 and C-597. The species found consisted of shiners (*Richardsonius balteatus*), chubs (*Mylocheilus caurinus*), suckers (*Catostomus macrocheilus*), and squawfish (*Ptychocheilus oregonensis*), the degree of abundance in the collections being about in the order named. These fish were taken only in shoal areas, where large schools were easily visible. No effect was made to obtain extensive collections in different types of habitat and consequently the samples taken show only some of the more abundant species. Visual observations throughout many parts of the lake, however, did indicate a relatively sparse juvenile fish population, as compared to the Priest Rapids - Paterson Section of the Columbia River. The National Park Service reported the collection of a small number of smallmouth bass, (*Micropterus dolomieu*), in some collections from sloughs in the vicinity of the Kettle Falls Ranger Station. No doubt many other species of juvenile such as sculpins, dace, chiselmouth, and carp are present but were not observed during this survey.

Gill netting for adult fish was also confined to Ranges C-694 and C-597. The record of gill-net catches is shown in table C-8. Each date represents one over-night bottom set with a net made up of 25 yards of 1-inch mesh and 50 yards each of 2-inch and 3-inch mesh. While the results of the limited gill-netting done could not be considered conclusive, a preponderance of undersirable and forage species is indicated. This condition is further borne out from reports of very poor takes of game and food species by fishermen.

The total catch at Range C-597 consisted of undesirable and forage species. All sets at Range C-694 contained one or more food and game species but in fewer numbers than undersirable and forage species. Squawfish and chubs made up by far the largest proportion of the catch, squawfish being taken in the greatest number of sets and chubs in the greatest numerical abundance. Suckers were less prevalent numerically, but were caught in all sets at Range C-694. Whitefish were the most abundant of the desirable species, several

Table C-8 - GILL-NET SETS, ROOSEVELT LAKE

Sampling Range	Date (1952)	Location of Nets	Depth of Set - Feet	Species Caught	Number of each Species	Range of Sizes (Inches)	Range of Weights (Ounces)
C-694	9/27	At East Shore, near confluence of Colville River	10 to 30	Sucker, *Catostomus macrocheilus*	2	18	24 - 32
				Whitefish, *Prosopium sp*	1	17	32
				" "	1	10	6
	9/28	At 1/4 distance from East Shore	15 to 50	Whitefish, *Prosopium sp*	1	10	6
				Squawfish, *Ptychocheilus oregonensis*	7	10 - 14	8 - 16
				Sucker, *Catostomus macrocheilus*	2	15 - 18	20 - 36
	9/29	At 1/2 distance from East Shore	125	Whitefish, *Prosopium sp*	3	16	24 - 30
				Sucker, *Catostomus macrocheilus*	1	15	20
	9/30	At West Shore across entrance of Sherman Creek	20 to 80	Chub, *Mylocheilus caurinus*	7	9 - 11	6 - 10
				Squawfish *Ptychocheilus oregonensis*	5	10 - 12	8 - 12
				" "	1	18	32
				Sucker, *Catostomus macrocheilus*	1	15	18
				Tench, *Tinca tinca*	1	14	30
				Yellow Perch, *Perca flavescens*	4	7 - 9	4 - 6
				Trout, Dolly Varden *Salvelinus malma*	1	12	16
C-597	9/25	At South Shore, near Warehouse Canyon. From Shore extending into Lake	5 to 35	Chub, *Mylocheilus caurinus*	41	8 - 11	6 - 10
				Squawfish, *Ptychocheilus oregonensis*	11	8 - 12	8 - 12
	10/1	Across Warehouse Canyon, before entrance into Lake	5 to 30	Chub, *Mylocheilus caurinus*	3	11	6 - 10
				Squawfish, *Ptychocheilus oregonensis*	5	18 - 20	30 - 44
				" "	5	10 - 12	8 - 12
				Tench, *Tinca tinca*	1	13	24

individuals being taken in all main channel sets at this cross-section.

The gill-net catch here is comparable to several previous catches in the Priest Rapids - Paterson Section of the Columbia River with similar nets. A preponderance of rough fish was also found in the downstream area. Chubs, however, were much more numerous in the Roosevelt Lake catches than in those in the lower section. Suckers were the most predominant fish in the downstream catches. Squawfish were equally prominent in both areas. A few more food and game fish, mostly smallmouth bass and blueback salmon, were generally found in the lower area catches.

Also of interest in the Roosevelt Lake fish was the extreme tapeworms parasitism observed in the chubs. Practically all specimens caught contained large tapeworms in their body cavities. In some specimens the sides of the fish were greatly distended and the body cavity completely full of the parasites. It is not known how widespread this parasitism is or to what extent it occurs in other fish. Extreme parisitism of this kind may have considerable effect on fish reproduction, and could well be considered for further investigation.

Other species of fish were observed or reported caught by fishermen in Roosevelt Lake. Among those seen during this survey were carp (Cyprinus carpio), and ling (Lota lota). Some carp were observed in nearly all sections. These fish are reported as being very abundant in some areas of the reservoir, especially near the mouth of the Kettle River, and are particularly noticeable in sloughs during the spring, when they congregate in large schools near shoal areas for spawning. From the limited observations, however, this species appears no more abundantly in the lake than in other sections of the river. In the Priest Rapids - Paterson Section large schools may be seen in practically every slough and also in many parts of the main stream. The only sample of ling seen was a large specimen washed ashore. This species is reported occasionally caught by fishermen in the lake.

Reports from the National Park Service and from fishermen in the area indicate sport fishing in Roosevelt Lake has been notably poor since the completion of Grand Coulee Dam in 1939. Prior to that time some migratory species, principally steelhead (Salmo gairdnerii) and chinook salmon (Oncorhynchus tshawytscha), were caught in the river. The establishment of the dam, however, cut off the migratory runs as the dam was too high for fish passage. Evidently the void created here was filled by rough fish, undesirable from the standpoint of sports fishermen. Little effort has been made since to establish more desirable species. Probably the most desirable species now caught are a limited number of Kamloops rainbow trout (Salmo gairdnerii kamloops) and an occasional Kakanee (Oncorhynchus nerka kennerlyi), a species native to the upper Columbia River system. Trout, including native rainbows (Salmo gairdnerii), brook (Salvelinus fontinalis), cutthroat (Salmo clarkii), and Dolly Varden (Salvelinus malma) are occasionally taken in the reservoir and are fairly abundant in some of the tributary streams.

Some fishing for smallmouth (Micropterus dolomieu) and largemouth (Micropterus salmoides) bass is said to exist seasonally in the lower Kettle River and in a few other areas of Roosevelt Lake.

From the biological standpoint Roosevelt Lake would be considered quite poor because:

1. The incoming waters, draining mostly mountain regions, contain little or no nutrient material for aquatic organisms.

2. Large amounts of suspended materials are added by incoming flows, especially during the annual spring floods, and are deposited on the lake bottom.

3. The ratio of incoming water to reservoir capacity is at times quite large, causing frequent replacement of the contents at certain seasons of the year.

4. The shores drop off sharply, giving very few shallow areas and consequently little aquatic vegetation.

5. The large winter drawdown interferes with the establishment of bottom organisms and creates conditions unfavorable for the natural reproduction of many species of fish.

RADIOLOGICAL STUDIES

Although it was not intended to make radiological studies at the time the Roosevelt Lake Survey was done, it was later decided to determine background or long-life radioisotopes in fish and plankton. The samples were collected in September 1952 and the examinations made in February 1953. The results are presented in table C-9.

The corrected counts were generally at or below the minimum detectable limits, as determined by the 95% confidence levels.(1) The results were so close to instrument background that they were considered not significantly different from "zero" counts. Samples were counted in both the internal flow and end-window tube counters, for 32 and 15 minutes, respectively.

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(1) Jarrett, Alan A., "Statistical Methods Used in the Measurement of Radioactivity - Some Useful Graphs". MonP-126, Contract No. W-35-058. Eng. 71. U.S. Atomic Energy Commission, June 17, 1946.

Table C-9 - RESULTS OF RADIOACTIVITY COUNTING FOR FISH AND PLANKTON - ROOSEVELT LAKE

Type of Sample	Beta Activity		Alpha Activity	
	Counts/min. (Corr. for background)	10^{-7} μc/gm	Counts/min. (Corr. for background)	10^{-7} μc/gm
Plankton	2.6 ± 2.6	190 ± 190	-0.10 ± 0.10	< 9
	-0.3 ± 2.3	< 430		
	1.4 ± 2.6	< 250	0.06 ± 0.17	<22
	0.3 ± 2.5	< 190	-0.13 ± 0.05	< 5
	-0.8 ± 2.4	< 530		
	-2.0 ± 2.5	< 170	0.22 ± 0.21	19 ± 18
Shiners (Juv.)	3.2 ± 2.6	18 ± 15		
	-1.1 ± 2.5	< 17	0.09 ± 0.17	< 1.6
	-0.7 ± 2.4	< 17		
	-1.4 ± 2.5	< 15	0.21 ± 0.20	1.7 ± 1.6
	1.8 ± 2.5	< 29		
	1.9 ± 2.6	< 18	-0.04 ± 0.11	< 1.1
	0.3 ± 2.4	< 16		
	-0.4 ± 2.5	< 13	0.19 ± 0.19	1.4 ± 1.4
	-0.1 ± 2.4	< 14		
	2.8 ± 2.6	25 ± 23	0.08 ± 0.15	< 1.9
	-1.1 ± 2.3	< 16		
	-1.9 ± 2.5	< 13	0.23 ± 0.20	1.7 ± 1.4
Squawfish (Juv.)	2.0 ± 2.5	< 34		
	-2.7 ± 2.4	< 24	-0.04 ± 0.11	< 1.5
	1.3 ± 2.4	< 20		
	-0.4 ± 2.5	< 20	-0.01 ± 0.12	< 1.4
	1.3 ± 2.5	< 28		
	-0.8 ± 2.5	< 19	-0.07 ± 0.11	< 1.2
Suckers (Juv.)	0.2 ± 2.5	< 13		
	-0.8 ± 2.5	< 14	0.0 ± 0.14	< 1.1
	0.7 ± 2.4	< 15		
	-2.4 ± 2.5	< 13	0.03 ± 0.15	< 1.1
	1.1 ± 2.5	< 22		
	-0.7 ± 2.5	< 27	-0.13 ± 0.01	< 0.2

Type of Sample	Beta Activity		Alpha Activity	
	Counts/min. (Corr. for background)	10^{-7} μc/gm	Counts/min. (Corr. for background)	10^{-7} μc/gm
Chub (Juv.)	0.7 ± 2.4	< 11		
	-0.2 ± 2.5	< 8	0.01 ± 0.11	< 0.5
Chub - Muscle	2.2 ± 2.5	< 13		
	0.6 ± 2.5	< 12	0.23 ± 0.20	1.6 ± 1.4
	1.4 ± 2.4	< 13		
	3.4 ± 2.5	16 ± 12	0.14 ± 0.17	< 1.2
Chub - Bone	-0.7 ± 2.3	< 61		
	-2.1 ± 2.5	< 40	0.05 ± 0.14	< 3.0
	0.3 ± 2.3	< 45		
	-2.2 ± 2.4	< 32	0.01 ± 0.12	< 2.1
Whitefish - Muscle	0.5 ± 2.3	< 11		
	2.5 ± 2.4	< 15	0.05 ± 0.14	< 1.2
Whitefish - Liver	1.5 ± 2.5	< 10		
	-0.2 ± 2.4	< 12	0.11 ± -.17	< 1.2
Whitefish - Bone	-0.1 ± 2.3	< 29		
	1.3 ± 2.5	< 22	0.11 ± 0.17	< 2.0
Sucker - Muscle	1.1 ± 2.4	< 12		
	0.0 ± 2.5	< 43	0.11 ± 0.17	< 1.3
Sucker - Liver	-1.4 ± 2.3	< 16		
	2.4 ± 2.5	< 24	0.01 ± 0.12	< 1.7
Sucker - Bone	-0.5 ± 2.3	< 26		
	1.3 ± 2.5	< 19	0.17 ± 0.18	< 1.9

SUPPLEMENTAL STUDIES

In order to determine certain characteristics of Roosevelt Lake at very low water levels, additional studies were made and samples collected on April 13 and 14, 1953. The reservoir was at the lowest point of drawdown for the year. Water level elevation was at 1,236 feet above mean sea level, 54 feet below the normal pool elevation of 1,290 feet above mean sea level.

OVERALL PROGRAM

Efforts were devoted principally to:

1. Bacteriological examinations to determine the extent of seepage through the Crescent Bay fill and the possible contamination near the irrigation water pump intake at the Dam, as well as any possible contamination in other parts of the lake during the extreme low water stages.

2. Mineral examinations to determine possible toxicity to aquatic organisms from heavy metals.

3. Visual observations to determine the extent of penetrations of finely suspended material from mine wastes into the reservoir at the very low water stages.

4. Plankton examinations to determine the possible build-up of any plankton organisms within the reservoir which may affect downstream water supplies or other water quality characteristics.

5. Added determinations of background radioactivity levels within the reservoir.

Water samples for M.P.N. Coliform organisms were taken at Ranges C-732, C-694, CSp-644, and C-597. The laboratory work was done by State Pollution Control Commission personnel at the City Health Department Laboratories in Spokane.

Physical and chemical examinations were made in the field on water samples from these same stations for temperature, turbidity, dissolved oxygen, pH, and methyl orange alkalinity. Composite surface samples for mineral determinations were taken at Ranges C-694 and C-732. Composite surface samples, varying from 2 to 6 liters, were taken at Ranges C-732, C-694, and C-597 for quantitative estimation of the number of plankton organisms. A few samples of plankton, algae, and juvenile fish were collected for background radioactivity determinations.

DISCUSSION OF RESULTS

The results for the supplemental studies in general confirm the findings of the previous work. The various aspects are discussed below.

Bacteriological Examinations

Highest values, 230 M.P.N. per 100 milliliters, were found at Range C-732, at Northport. This was less than the results of last September, when highest values were found at this range. At midstream on Range C-694 a high value of 230 M.P.N. per 100 milliliter was also found, other results across this range reaching a maximum of 60 M.P.N. per 100 milliliters. Results at Range C-597, near Grand Coulee Dam were all less than 45 M.P.N. per 100 milliliters, indicating no seepage through the fill separating Crescent Bay and Roosevelt Lake during the time of this survey. It should be noted, however, that the Bureau of Reclamation has on some occasions detected seepage through this temporary fill and therefore a public health hazard still exists.

The results of the bacteriological examinations are given in table C-10, below.

Table C-10 - BACTERIOLOGICAL ANALYSES, SUPPLEMENTAL STUDIES

Sampling Range	Distance from South or E. Shore	Date (1953)	MPN per 100 ml.	Sampling Range	Distance from South or E. Shore	Date (1953)	MPN per 100 ml.
C-732	E. Shore	4/14	230	C-597	Bel. Cres. Bay Fill	4/13	<45
C-694	E. Shore	4/14	<45				
	1/4		<45		Pump Pl. Intake		<45
	1/2		230		1/2		<45
	3/4		<45		3/4		<45
CSp-644	1/2	4/13	60				

Physical and chemical examinations

Turbidity in the river above the present backwater and in the upper part of the reservoir was somewhat higher than previously. This turbidity was caused by the flour-like material observed in the earlier study. The extent of penetration of this material into the reservoir was much further than at the higher water stages, extending at this time to beyond the mouth of the Colville River, Range C-694. Deposits of this material were visible in the areas exposed by the drawdown for approximately 20 miles below Northport. A slight turbidity and greenish cast observed in the lower reservoir was in all probability due to phytoplankton.

Water temperatures were, of course, much lower during this late winter period than in the previous survey, with the tributaries somewhat warmer than the lake proper. No thermal stratification was indicated in the deeper waters. The pH values were somewhat less in the lower reservoir than previously. Dissolved oxygen values were at or near saturation. The results are presented in table C-11.

Table C-11 - ANALYTICAL RESULTS, SUPPLEMENTAL STUDIES

Sampling Range	Distance From South or E. Shore	Depth Ft.	Date (1953)	Turb. ppm	Temp. °C	D.O. ppm	pH	M.O. Alk. ppm
C-732	10'	1	4/14	26	6.5		7.6	72
C-694	1/2	1	4/14	13	6.5	10.8	7.6	70
CSp-644	1/2	1	4/13		9.5	9.8	7.2	48
C-597	1/2 1/2	1 200	4/13	7	5.5 5.5	10.2 10.8	7.7	65

Mineral analyses of water samples taken in the upper reservoir showed little change from previously determined conditions. Although values for zinc were somewhat higher, values for heavy metals were below those generally considered toxic to aquatic organisms. The laboratory results are shown in table C-12.

Table C-12 - MINERAL ANALYSES, SUPPLEMENTAL STUDIES

Analysis	Range C-732		Range C-694
	Unfiltered	Filtered	Unfiltered
	4/14/53 @ 1' depth	4/14/53 @ 1' depth	4/14/53 @ 1' depth
Ca-ppm			21
Mg	4.5		4.8
Fe	0.10		0.07
Mn	0.04	0.04	0.27
Zn	0.075	0.033	0.01
Cu	0.023	0.022	0.010
SO_4			17
PO_4	0.07		0.05
NO_3	0.24		0.32
Tot. Sol.	120		110
Na			1.8
Si			9.3
Cl	0.21		0.18
Pb	0.025		0.026
Spec. Cond. µmhos/cm	98		93

Biological Examinations

Biological examinations during this brief survey were confined primarily to a numerical estimation of plankton. Phytoplankton populations were much higher than found in the fall survey, especially in the lower part of the reservoir where a quite heavy pulse of the diatom Asterionella sp was found to occur. This no doubt adds to the increase in this form previously found abundant in the Priest Rapids - Paterson Section of the Columbia River during May and June. It may also have some effect on the clogging of water supply filters, reported downstream from the reservoir. Concentrations of this organisms also produced a noticeably fishy odor. The heavy pulse of crustaceans in lower Roosevelt Lake, observed last fall, was not evident at this time. Plankton results are shown in table C-13.

Table C-13 - PLANKTON RESULTS, SUPPLEMENTAL STUDIES

	Range C-732	Range C-694	Range C-597	
Date of Sample (1953) Location of Sample	4/14 E. Shore	4/14 Cross-Sect.	4/13 Cross-Sect.	
	ORGANISMS PER MILLILITER			
BACILLARIOPHYCEAE - TOTAL	166	274	1,006	969
Asterionella sp	140	215	898	839
Cyclotella sp		3	20	10
Fragillaria sp	2	3	7	5
Melosira sp			2	10
Navicula sp	1	6		2
Synedra sp	3	2	25	20
Tabellaria sp	15	24	42	66
CHLOROPHYCEAE - TOTAL	1	3	111	83
Ankistrodesmus sp		3	96	76
PIGMENTED FLAGELLATES - TOTAL		1	7	42
	ORGANISMS PER 200 MILLILITERS			
PROTOZOA - TOTAL	6	2	2	3
FILAMENTOUS BACTERIA AND FUNGI - TOTAL	2			
ROTIFERA - TOTAL	2		2	7
MISCELLANEOUS	4	16	11	6
TOTAL ORGANISMS PER MILLILITER	167	278	1,124	1,094

A superficial examination of riffle areas near Northport, covered with approximately 20 feet of water at normal reservoir levels, indicated a very poor bottom fauna. Heavy deposits of rock flour were noted on rocks in this area.

Observation of the exposed areas and mud flats in the drawdown areas showed an absence of vegetation. Quite large areas of these exposed mud flats exist at intervals in the upper reservoir from below Northport to near Gifford Ferry, with a few such smaller areas in the lower reservoir.

Radiological Examinations

Water and biological samples were collected at Ranges C-694 and C-597 and examined for radioactivity within a week after collection. A total of six samples were used for this purpose, two of water, two of plankton, one of algae, and one of juvenile fish.

In general, activities were all at or below the background level. One plankton portion, collected at Range C-597, near Grand Coulee Dam, showed a noticeable amount of alpha activity but such activity was not found in any other portions of the same or similar samples. It is possible that the activity may have been due to some particulate matter derived from uranium mining operations reported some 40 miles upstream from Grand Coulee Dam.

APPENDIX "D"

WATER QUALITY STUDIES

BONNEVILLE RESERVOIR - OREGON AND WASHINGTON

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ABSTRACT

The study of the Bonneville Reservoir was carried out as a part of the Columbia River Studies project of the Public Health Service. Two main objectives of the overall program were (a) to determine the effects of impoundments upon stream water quality and (b) to determine the effects of radioactive materials upon the normal chemical, physical, and biological parameters of stream water quality. Data from the Bonneville Area were intended to supplement the information from the upstream area and to assist in predicting the effects of the impoundments.

The Bonneville Reservoir is a "run-of-the-river" impoundment, developed primarily for power purposes and with little or no provision for flood storage. The McNary Reservoir area, located some 150 to 200 miles above Bonneville Dam and developed for the same purpose, was studied prior to operation of the impoundment.

The studies in the Bonneville Reservoir involved, essentially, the collection of samples of water, aquatic organisms, and bottom muds and, from them, the determination of existing physical, chemical, bacteriological, biological, and radiological conditions.

The results of this study showed that:

1. The physical and chemical conditions were fairly uniform throughout the reservoir and were well within the limits expected to support a good mixed aquatic biota. The only exceptions were the occurrence of considerably higher values for ammonia nitrogen at several of the sampling points and a slight temperature increase from the upper to the lower end of the pool.

2. There was little or no build-up of plankton within the reservoir during the period of the study. The forms present were quite similar to those found in unimpounded portions of the Columbia River and occurred in the same relative proportions. There was a possible slight increase in green and blue-green algae, and in protozoans.

3. The physical nature of the pool bottom was such as to discourage the establishment of bottom animals. Most of the river bed seemed to be covered with a layer of fairly coarse to fine sand, considerable debris, and some mud deposits. The pool areas therefore appeared to be much less productive of bottom organisms than were unimpounded areas. The organisms present were also of a less desirable type from the standpoint of serving as fish food.

4. Juveniles of shiners, squawfish, and chiselmouth were the predominant species, according to the fish collections. The presence of a few young bass and crappie indicated at least some successful spawning of spiny-rayed species within the pool area. Juvenile salmon are probably abundant during certain seasons of the year but would not be expected during the period of this study.

5. There was a uniform mixing of the radioactive elements across the width of the reservoir and a gradual decrease of radioactivity between the upper and lower ends of the impoundment.

6. Measurable quantities of radioactivity were present in all the types of aquatic organisms examined throughout the pool. However, the order of magnitude was such that it would be expected to have little or no effect on these organisms, or on their use.

Due to rough water the collection of adult fish was very limited. Several sturgeon and one squawfish were caught by gill nets. There is some commercial fishing in the area, mostly for blueback and chinook salmon, and to some extent for sturgeon. A few parts are considered excellent for sport fishing, mostly for steelhead trout, but catches of chinook salmon, resident trout, sturgeon, and squawfish have also been reported from the pool area and the mouths of tributary streams.

GENERAL INFORMATION

The main purpose of the Bonneville Reservoir Study was to obtain data on the limnological and radiological status of a Columbia River impoundment which had been in operation for several years. It was expected that the survey would yield data useful in predicting the future effect of McNary Reservoir (a similar type of impoundment expected to be placed into operation in 1953 and located approximately 150 miles upstream from Bonneville Dam) on stream water quality. The data obtained were also expected to be useful to other agencies participating in or interested in this study.

PARTICIPATING AGENCIES

Several Federal agencies assisted in the conduct of the survey, each one having certain interests in the results.

The U. S. Corps of Engineers is interested in the chemical quality of the water as it might affect the turbines and other machinery at the Bonneville Dam Power Plant. The Corps is also interested in overall limnological conditions, particularly from the standpoint of their effect on the passage of fish over the dam and through the impoundment.

The U. S. Fish and Wildlife Service is interested primarily in limnological conditions and possible effects on fish management or rehabilitation programs. The State Health Authorities are interested in sanitary water quality as affected by municipal or industrial waste discharges. The Public Health Service Northwest Drainage Basins Office is interested from the standpoint of their overall responsibilities in the pollution abatement and control programs in the Pacific Northwest.

GENERAL PLAN OF OPERATION

This survey was conducted during the period August 18 through 29, 1952. It was felt that with the limited time available it was best to do the study during low water stages and during a period of maximum water temperatures. The greatest concentrations of chemical constituents and highest biological activity would normally be expected under such conditions.

Six sampling ranges were established within the reservoir area. Each range was designated by a mileage index number, which gives the distance, in miles, from a fixed reference point established by the U. S. Corps of Engineers at the mouth of the Columbia River. The use of this system permits a tie-in with the Public Health Service studies made in the Priest Rapids - Paterson section, as well as with studies made by various agencies in other sections of the Columbia River Basin. Sampling points were located from the standpoint of obtaining information on the impoundment as a whole. The limited time available for the study precluded the collection of information from individual sources of pollution and major tributaries. The area covered by the study and the location of sampling points are shown in figure D-1.

The sampling ranges established for the studies were as follows:

1. C-191: One mile above the Dalles, Oregon; set up as a control

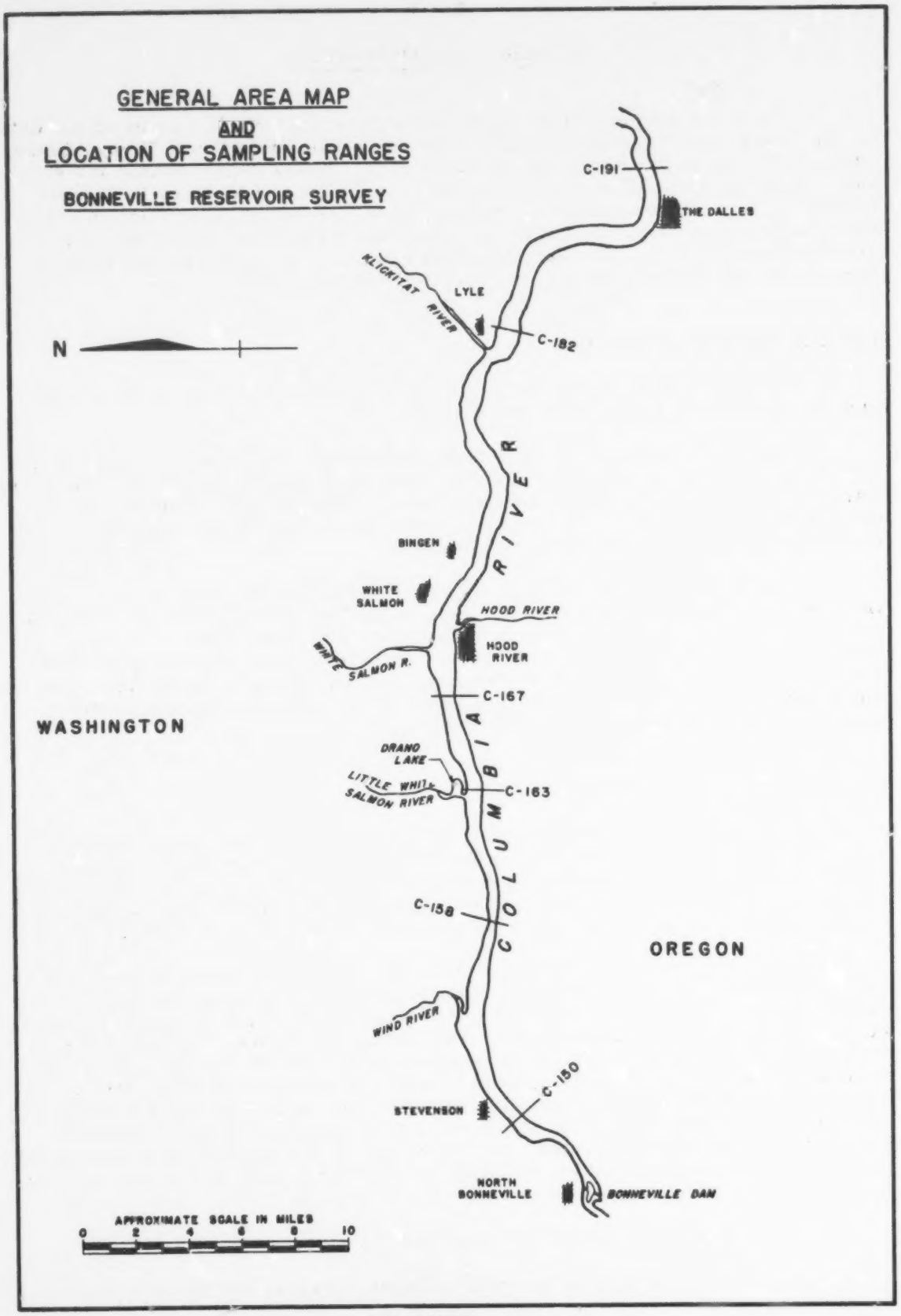
GENERAL AREA MAP
AND
LOCATION OF SAMPLING RANGES
BONNEVILLE RESERVOIR SURVEY
N
C-191
THE DALLES
KLICKITAT RIVER
LYLE
C-182
COLUMBIA RIVER
BINGEN
WHITE SALMON
HOOD RIVER
HOOD RIVER
WHITE SALMON R.
C-167
WASHINGTON
DRANO LAKE
LITTLE WHITE SALMON RIVER
C-163
C-158
OREGON
WIND RIVER
C-150
STEVENSON
NORTH BONNEVILLE
BONNEVILLE DAM
APPROXIMATE SCALE IN MILES
0 2 4 6 8 10

FIGURE D-1

station. It is actually within the backwater area but has a much more rapid flow and conditions here would closely approximate actual stream conditions. It is also above any suspected source of pollution entering the reservoir directly.

2. C-182: Immediately above Lyle Ferry, but well below The Dalles, Oregon.

3. C-167: One mile below the mouth of the White Salmon River. This range is also below the Hood River and the towns of Hood River, Oregon, and White Salmon and Bingen, Washington.

4. C-163: Immediately above the mouth of the Little White Salmon River. Very limited sampling was done at this range.

5. C-158: Near Collins Point Light. Biological sampling point only.

6. C-150: One mile below Stevenson, Washington. This was the furthest downstream point which was readily accessible for sampling.

Space for a field laboratory was made available by the U. S. Fish and Wildlife Service at their Little White Salmon Hatchery, located at the upper extremity of Drano Lake. Simple chemical and biological operations were performed there. Other more complex determinations, such as mineral analyses and radiological examinations were made in the Public Health Service laboratory at Richland, Washington. Bacteriological analyses were made by the Oregon State Sanitary Authority at Portland, Oregon.

Personnel assigned to the field study included two biologists and one chemist from the Columbia River Studies group and one biologist from the PHS Northwest Drainage Basins Office. Other personnel from the Columbia River Studies group collected some of the samples and picked up others at the site of collection for return to the Richland laboratory. Personnel from the Oregon State Sanitary Authority transported the bacteriological samples from the site of collection to their laboratory.

It was originally planned to collect most of the samples from small aluminum boats (14' and 16') equipped with outboard motors (10 and 25 horsepower). This did not prove feasible, however, as the water was too rough during a large portion of the survey period for safe handling of these craft. Consequently a commercial fishing boat was rented for at least a part of the sampling.

DESCRIPTION OF THE RESERVOIR

The Bonneville Reservoir is a body of water approximately 50 miles long, one-half to one and one-half miles wide and generally varying from 30 to 100 feet in depth, created by the impoundment of the Columbia River by Bonneville Dam. It extends from the Dam to a point just above The Dalles, Oregon. This dam, a so-called "run-of-the-river-dam", is located approximately 40 river miles east of Portland, Oregon and 140 river miles above the mouth of the stream. Constructed mainly for the production of hydro-electric

power, it has several built in features, such as fish ramps for the passage of migratory fish and navigation locks for ship traffic. The structure was built by the U. S. Corps of Engineers and placed in operation in 1938.

STREAM FLOWS

River flows were quite uniform during the survey and the reservoir was at normal pool elevation, 72 feet above mean sea level, throughout the period of study. Average daily flows at The Dalles varied from 119,000 to 132,000 c.f.s., with an overall average of 125,800 c.f.s. The flows were somewhat above minimum low flows which may be reached later in the fall or winter, but well below the average annual spring flood flow of 585,000 c.f.s. Pool elevations may reach a maximum of 82.5 feet above mean sea level during the high run-off periods. Maximum flows normally occur in June and the minimum in December.

At The Dalles the maximum average daily flow of record is 1,160,000 c.f.s., and this occurred in June of 1894. The minimum average daily flow, recorded on several occasions, has been in the neighborhood of 40,000 c.f.s.

Surface velocities, during the period of the survey, appeared to be much higher at the control section (Range C-191) than at other sections. The estimated velocity was about 3 feet per second, as against 1 foot per second or less at ranges within the reservoir.

SURVEY PROCEDURES

Samples of water, aquatic organisms, and bottom muds were collected and examined for the determination of physical, chemical, bacteriological, biological, and radiological conditions. The results are discussed in a later section of the report. The procedures used for collection and examination of these samples are described briefly in this section.

Chemical and physical determinations on individual samples included those for turbidity, temperature, dissolved oxygen, alkalinity, pH, free carbon dioxide, ammonia, nitrites, phosphates, and specific conductivity. Analyses for calcium, magnesium, iron, manganese, zinc, copper, sulfates, nitrates and total solids were made on composite, cross-sectional surface samples taken at some of these ranges. Biological collections included plankton, filamentous algae, bottom organisms, and fish. Bacteriological samples were obtained at stations designated by the Oregon State Sanitary Authority. Water, plankton, algae, bottom organisms, fish (juvenile and adult), and bottom muds were taken for determination of gross beta activity densities. Alpha activities were also determined on bottom mud samples.

COLLECTION OF SAMPLES

The collection of various types of samples was in accordance with procedures used or adapted for the studies in the Priest Rapids - Paterson section of the Columbia River.

Water

Samples of water for field determination of temperature, turbidity, dissolved oxygen, alkalinity, pH, and free carbon dioxide were taken with a 3-liter Kemmerer sampler, at the surface and near the bottom. Collections were made at quarter points across all of the ranges. For the remaining chemical and physical examinations 1,000-milliliter surface and depth samples were obtained at the quarter points on Ranges C-191, C-167, and C-150. Five-gallon composite surface samples were taken at these same three ranges for determination of the mineral constituents.

Two sets of surface samples for bacteriological examinations were taken only near the two shores and at the quarter points on Ranges C-182 and C-167. For the determination of radioactivity densities, 1,000-milliliter surface samples were obtained from Ranges C-191, C-167, and C-150.

Aquatic Organisms

Composite water samples from the surface and near the bottom were obtained at all ranges for plankton count and weight determinations. Tows were also made with a standard silk bolting cloth net (number 20) at each range to determine the presence and relative abundance of some of the larger plankton organisms (zooplankton).

Quantitative bottom organisms samples were taken with an Ekman dredge, where possible, at each range. Other collections were made at various shore points by picking from rocks and by seining.

Juvenile fish collections were made at shore points at each of the various locations by seining with a 10-foot, 1/4-inch-mesh minnow seine. Adult fish collections were taken with gill nets, but only a few specimens were caught. Much of the information on fish was obtained by observations at the Bonneville Dam fish ladders and through conversations with local sports fishermen, commercial fishermen, and others.

Bottom Muds

A limited number of bottom mud samples were collected with the Ekman Dredge. Portions weighing about 20 grams (after oven-drying) were used to determine the radioactivity.

LABORATORY METHODS

The laboratory methods used for many of the routine examinations were taken from various standard sources. Other procedures were those developed for the main portion of the Columbia River Studies, in the Priest Rapids - Paterson Section.

Chemical and Physical Examinations

Analytical techniques for most of the chemical and physical examinations were those given in "Standard Methods for the Examination of Water and Sewage", 9th Edition, American Public Health Association, with some modifications to fit the field conditions.

Surface water temperatures were read from a regular Centrigrade thermometer, while depth temperatures were taken with a Negretti-Zambra reversing thermometer. Surface turbidity readings were read with a USGS Standard Water Turbidity Scale. Analyses for dissolved oxygen, free CO_2, pH, and alkalinity were made in the field with a portable chemical kit. All other tests were done at the Richland laboratory. The methods for determining copper and zinc were taken from "Colorimetric Determination of Traces of Metals", by E. P. Sandell (Interscience Publishers, Inc., 1950). Specific conductances were determined with an Industrial Instrument Company Solu Bridge, Model RD-R-4.

Bacteriological Examinations

As already stated, examinations for the bacteriological samples were made at the laboratories of the Oregon State Sanitary Authority at Portland, Oregon. Laboratory methods used were those given in "Standard Methods", IX.

Biological Examinations

Procedures for the collection and examination of aquatic organisms generally followed those given in "Limnological Methods", by P. S. Welch. (The Blakiston Company, 1948).

Two-liter water samples for count and 10-liter samples for weight were centrifuged in a Foerst Centrifuge, the organisms removed, and preserved for plankton counts and weights. Later, in the Richland laboratory, the organisms were identified and counts made in a Sedgewick-Rafter counting cell. Weights were determined after drying at 60°C for 24 hours. The organic

content was found by ashing in a muffle furnace at 600°C for 30 minutes and reweighing.

Bottom organisms samples were sorted, identified to order, counted, and weighed. Juvenile fish samples were sorted and data on relative abundance of species recorded. For adult fish the data included approximate length, weight, sex, and species of each specimen.

Radiological Examinations

The radiological examinations included the determination of gross beta activity densities on samples of water, plankton, filamentous algae, bottom organisms, fish, and bottom muds. Alpha activity was determined on the bottom muds. Field collections were made as previously discussed for these various types of samples.

Water samples were prepared for counting by acidifying and evaporating nearly to dryness in beakers. The sample was then transferred to a small stainless steel dish, 1 inch in diameter, for complete evaporation. After final drying, the dish was muffled for 1 minute in a 600°C oven and the contents counted. Aquatic organisms were prepared for radioactivity counting by digesting in nitric acid, evaporating, ashing, and plating on the stainless steel dish.

Radioactivity counts for bottom muds were made on the residue obtained by the extraction of the radioactive elements from the mud particles. This was deemed necessary in view of the low count per gram of dry weight and the large correction factors resulting from the use of a large and dense sample.

All beta counting was done in Geiger-Mueller, end-window tube counters. Internal flow counters were used for alpha determination..

It was necessary to obtain correction factors for decay, self-absorption, and air and mica-window absorption. These factors were determined on a few representative samples of each of the types examined and then applied to individual counts to give absolute values in terms of microcuries per milliliter or per gram.

DISCUSSION OF RESULTS

The total number of samples collected and analyses made are given in table D-1. The results of the laboratory examinations are discussed below.

Table D-1 - SUMMARY OF SAMPLING AND LABORATORY LOAD

Examination	No. Samples	Determinations
Bacteriological	20	20*
Chemical and Physical		
Routine	115	760
Mineral Analyses	9	81
Biological		
Bottom Organisms	11	11
Plankton	46	46
Radiological		
Water	27	27
Biological Specimens	184	184
Bottom Muds	8	16
Decay Studies	17	17

* Examinations made by Oregon State Sanitary Authority Laboratories.

BACTERIOLOGICAL EXAMINATIONS

Though only two sets of surface samples were collected at each range there is an indication that the domestic pollution, as shown by the coliform results, is principally on the Oregon shore. The highest MPN value, 700 per 100 ml., occurred about 7 miles below The Dalles, Oregon, at Range C-182, and in the relatively shallow, quiet water 2 miles below the city of Hood River, near the south shore of the Columbia River. It should be noted that low values were found on the Oregon side as well as elsewhere on August 19, but there is no apparent explanation for such values, especially in view of the strong upstream winds occurring on that particular day. The results of the bacteriological analyses are presented in table D-2.

CHEMICAL AND PHYSICAL EXAMINATIONS

There was a slight variation in turbidity readings, values of from 10 to 20 p.p.m. being observed. Similar readings were obtained at all ranges but probably from different causes. From the difference in color observed, it would appear that the slight turbidity at the control section, Range C-191, was caused by suspended silt while that at other ranges was caused by plankton forms.

Table D-2 - RESULTS OF BACTERIOLOGICAL ANALYSES

Distance from North Shore	Date (1952)	M.P.N. per 100 mls. Range C-182	Range C-167
100'	8/19	230	45
	8/27	240	23
1/4	8/19	230	45
	8/27	62	23
1/2	8/19	45	60
	8/27	62	23
3/4	8/19	45	230
	8/27	700	700
S. Shore (100')	8/19	60	-
	8/27	62	700

Water temperature readings were approximately the same for surface and depth samples at all ranges, and showed no thermal stratification anywhere within the pool. Average temperatures were slightly higher at all ranges below The Dalles, thus indicating a slight warm-up within the pool.

Dissolved oxygen values were fairly uniform and consistently high at each range, approaching saturation in all cases. Results obtained from samples taken in deep water near the bottom were only very slightly below those at the surface, indicating a thorough mixing of the water and little oxygen demand from bottom deposits. Average values were slightly less at the lower ranges.

The average values for ammonia nitrogen at all ranges were much higher than had been found in the Priest Rapids - Paterson section of the Columbia River. Data ranged from a low of 0.06 p.p.m. to a high of 1.60 p.p.m. The highest results were found below Hood River on the Oregon side, and below Stevenson on the Washington side. Average values for nitrate nitrogen ranges from 0.02 to 0.11 p.p.m., the higher figures being found near Stevenson. No nitrite nitrogen was detected in any of the samples.

Values for specific conductance were generally quite low on all samples, averaging about 190 micromhos per centimeter at all ranges.

Data for pH and alkalinity were fairly uniform at all ranges, pH varying from 8.3 to 8.6 and methyl orange alkalinity from 68 to 72 p.p.m. Phenolphthalein alkalinity values from 3 to 10 p.p.m. were found, with no noticeable variation between ranges. The values for pH and phenolphthalein alkalinity were somewhat higher than those found in the Priest Rapids - Paterson section of the Columbia River. No free CO_2 or mineral acidity was found in any of the areas sampled.

The findings on the mineral analyses of water were comparable and

uniform at all ranges. Average values were: 19 p.p.m. for calcium, 6.0 p.p.m. for magnesium, 0.30 p.p.m. for iron, and 15 p.p.m. for sulfates. Traces of other metals were also found to be present, with average concentrations of 0.02 p.p.m. for manganese, 0.003 p.p.m. for zinc, and 0.004 p.p.m. for copper. Phosphate values were fairly uniform throughout the pool, averaging 0.05 to 0.06 p.p.m.

As a whole, the physical and chemical conditions throughout the reservoir were reasonably uniform and well within limits generally considered favorable for the support of a good mixed aquatic biota. The only noticeable difference within the pool itself were the considerably higher values for ammonia nitrogen, obtained at several points, and a possible slight temperature increase from upper to lower sections of the pool.

The only significant differences between conditions in the pool and those in the Priest Rapids - Paterson section of the river were, in addition to increased ammonia nitrogen and iron values, a somewhat higher pH and an increase in phenolphthalein alkalinity. It is not believed these differences are due to the impoundment but, rather, to a build-up of these constituents in the river between Paterson and the headwaters of the Bonneville pool.

The above data indicate that little change in water quality characteristics occur in a "run-of-the-river" impoundment, such as Bonneville Reservoir.

The results of the chemical, physical, and mineral examinations are given in tables D-3 and D-4.

LIMNOLOGICAL EXAMINATIONS

As has already been stated, the chemical and physical conditions in the reservoir are well within the limits generally considered favorable for supporting a good mixed aquatic biota.

Plankton

The variation in plankton between samples taken at the same range was as great as or greater than the difference between ranges. Thus, little change in numbers, weight, or types of organisms was found between ranges. The samples indicated a fairly uniform distribution of plankton throughout the pool and little change in composition from surface to bottom. The weight of plankton appeared to depend more on the presence of silt than upon the number of organisms present. The average number of organisms in this area (2,500 - 4,500 per ml.) was considerably higher than had been found during a similar period in the upper Columbia River (Priest Rapids - Paterson Section), but not as high as had been found in some of the tributaries above McNary Dam.

Diatoms were the predominant form, making up from 85 to 90% of the total number of plankters present. The remaining population consisted of from 10 to 15% single-celled green algae and 1 to 5% blue-green algal forms. The number of protozoans, while not abundant percentage-wise as compared to the other organisms, were much more abundant than in the Priest Rapids - Paterson Section, averaging as high as 1,175 per 200 ml. in surface samples taken in the lower reservoir. There was evidently no build-up of the other zooplankton within the pool. A few rotifers were present at all ranges but microcrustaceans were extremely scarce.

Table D-3 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES

Sampling Range	Distance from North Shore	Date (1952)	Turbidity ppm	Temp. °C.	D.O. ppm	NH_3 ppm	NO_2 ppm	PO_4 ppm	Spec. Cond. µmhos per cm.	Alkalinity ppm		pH
										M.O.	Phen.	
C-191	1/4 (Surface)	8/20	14	19.0	12.4	0.30	0	0.07	200	71	5	8.4
		8/25	19	19.0	12.3	0.06	0	0.07	190	70	9	8.6
		8/27	13	19.0	11.7	0.32	0	0.01	180	70	7	8.4
	1/4 (70' Depth)	8/25		19.0	11.6					70	10	8.5
	1/2 (Surface)	8/20	14	19.0	12.4	0.72	0	0.07	200	72	5	8.4
		8/25		19.0	11.5	0.14	0	0.09	190	71	10	8.5
		8/27	12	19.0	11.7	0.38	0	0.01	180	71	8	8.4
	1/2 (80' Depth)	8/25		19.0	11.6					70	9	8.5
	3/4 (Surface)	8/20	14	19.0	12.3	0.64	0	0.07	200	72	7	8.4
		8/25		19.0	11.5	0.16	0	0.06	190	69	10	8.5
		8/27	12	19.0	11.7	0.28	0	0.03	180	71	8	8.4
	3/4 (30' Depth)	8/25		19.0	11.7					68	9	8.5
C-182	1/4	8/19	20	20.0	10.3					71	8	8.4

Note: Free CO_2 = 0 for all samples taken throughout survey.

Table D-3 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (Continued)

Sampling Range	Distance from North Shore	Date (1952)	Turbidity ppm	Temp. °C.	D.O. ppm	NH_3 ppm	NO_2 ppm	PO_4 ppm	Spec. Cond. µmhos per cm.	Alkalinity ppm		pH
										M.O.	Phen.	
C-182 (cont.)	1/4 (Surface)	8/24	15	20.0	11.8					72	10	8.5
		8/27		19.0	10.8					70	8	8.4
	1/4 (55' Depth)	8/24		20.0	11.8					69	10	8.5
	1/2 (Surface)	8/19	20	20.0	10.2					69	6	8.4
		8/24	15	20.0	11.8					70	9	8.5
		8/27		19.0	10.8					70	7	8.4
	1/2 (34' Depth)	8/24		20.0	11.8					70	8	8.5
	3/4 (Surface)	8/19	20	20.0	10.4					71	6	8.4
		8/24	15	20.0	11.8					70	8	8.5
		8/27		19.0	10.8					70	7	8.4
	3/4 (15' Depth)	8/24		20.0	11.8					71	9	8.5
C-167	1/4 (Surface)	8/20	17	19.5	9.9	0.32	0	0.04	200	68	2	8.3
		8/22	17	19.5	11.8					71	7	8.4

Table D-3 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (Continued)

Sampling Range	Distance from North Shore	Date (1952)	Turbidity ppm	Temp. °C.	D.O. ppm	NH_3 ppm	NO_2 ppm	PO_4 ppm	Spec. Cond. µmhos per cm.	Alkalinity ppm		pH
										M.O.	Phen.	
C-167 (cont.)	1/4 (Surface)	8/25	20	20.0	10.5	0.08	0	0.06	190	68	8	8.5
		8/27	11	19.5	10.8	0.24	0	0.02	180	70	9	8.5
	1/4 (90' Depth)	8/20		19.5	9.8	0.08	0	0.10	200	67	3	8.4
		8/22			11.7					70	7	8.4
		8/25		20.0	10.5	0.40	0	0.03	190	69	9	8.6
		8/27		19.5	10.8	0.06	0	0.04	180	68	8	8.4
	1/2 (Surface)	8/20	17	19.5	9.8	0.44	0	0.06	200	68	3	8.4
		8/22	17	19.5	11.9					70	8	8.4
		8/25	20	20.0	10.6	0.10	0	0.04	190	69	9	8.6
		8/27	10	19.5	10.7	0.30	0	0.03	170	69	8	8.5
	1/2 (60' Depth)	8/20			9.9	0.80	0	0.06	200	66	2	8.3
		8/22			12.0					71	8	8.4
		8/25			10.5	0.20	0	0.04	190	68	8	8.5
		8/27		19.5	10.6	0.72	0	0.07	170	68	6	8.4
	3/4 (Surface)	8/20	17	19.5	10.0	0.52	0	0.03	200	67	3	8.4
		8/22	17	19.5	11.5					70	8	8.4
		8/25	20	19.5	10.4	1.60	0	0.20	190	66	9	8.5
		8/27	11	19.5	10.6	1.60	0	0.09	170	68	6	8.4

Table D-3 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (Continued)

Sampling Range	Distance from North Shore	Date (1952)	Turbidity ppm	Temp. °C.	D.O. ppm	NH_3 ppm	NO_2 ppm	PO_4 ppm	Spec. Cond. µmhos per cm.	Alkalinity ppm		pH
										M.O.	Phen.	
C-167 (cont.)	3/4 (30' Depth)	8/20			9.9	0.20	0	0.13	200	66	3	8.4
		8/22			11.3					71	8	8.4
		8/25			10.5	1.60	0	0.06	190	67	8	8.5
		8/27			10.7	0.80	0	0.05	170	70	6	8.4
C-163	1/4 (Surface)	8/22	15	19.5	11.2					72	5	8.4
	1/4 (23' Depth)	8/22		19.5	11.5					69	7	8.4
	1/2 (Surface)	8/22	15	19.5	11.6					71	6	8.4
	1/2 (45' Depth)	8/22		19.5	11.5					71	7	8.4
C-150	1/4 (Surface)	8/20	15	20.0	10.6	0.22	0	0.01	200	72	2	8.4
		8/25		19.5	9.9	0.14	0	0.06	190	68	7	8.4
		8/27	10	19.5	10.2	1.60	0	0.16	180	70	8	8.4
	1/4 (80' Depth)	8/20		20.0	10.2	0.28	0	0.01	200	73	2	8.3

Table D-3 - SUMMARY OF ANALYTICAL RESULTS ON RIVER WATER SAMPLES (Continued)

Sampling Range	Distance from North Shore	Date (1952)	Turbidity ppm	Temp. °C.	D.O. ppm	NH_3 ppm	NO_2 ppm	PO_4 ppm	Spec. Cond. µmhos per cm.	Alkalinity ppm		pH
										M.O.	Phen.	
C-150 (Cont.)	1/4 (80' Depth)	8/25		19.5	9.8	0.06	0	0.08	190	69	8	8.5
		8/27		19.5	10.0	0.48	0	0.01	180	69	7	8.4
	1/2 (Surface)	8/20	15	20.0	10.6	0.42	0	0.01	200	72	1	8.3
		8/25	14	19.5	9.9	0.18	0	0.03	190	68	7	8.5
		8/2.	10	19.0	10.2	1.60	0	0.05	180	68	7	8.4
	1/2 (64' Depth)	8/20		20.0	10.6	0.48	0	0.01	200	70	0	8.3
		8/25		19.5	9.8	0.04	0	0.02	190	69	7	8.4
		8/27		19.0	10.2	0.48	0	0.04	180	69	8	8.4
	3/4 (Surface)	8/20	15	20.0	10.6	0.80	0	0.11	200	71	1	8.3
		8/25	17	19.5	9.9	0.08	0	0.06	190	69	6	8.4
		8/27	13	19.5	10.2	0.80	0	0.02	180	68	7	8.4
	3/4 (30' Depth)	8/20		20.0	10.5	0.20	0	0.01	200	72	2	8.4
		8/25		19.5	9.8	0.14	0	0.04	190	69	6	8.4
		8/27		19.0	9.8	0.48	0	0.07	180	69	6	8.4

Table D-4 - RESULTS OF MINERAL ANALYSES ON RIVER WATER SAMPLES
(Cross-Section Samples)

Sampling Range	Date (1952)	Ca	Mg	Fe	Mn	Zn	Cu	SO_4	NO_3	Total Solids
		Concentration - Parts per million								
C-191	8/20	20	5.3	0.55	0.03	0.003	0.006	15	0.00	110
	8/25	18	6.0	0.21	0.02	0.000	0.004	15	0.03	100
	8/27	19	6.4	0.19	0.02	0.005	0.005	16	0.01	130
C-167	8/20	20	5.2	0.10	0.03	0.004	0.004	15	0.00	100
	8/25	18	6.2	0.41	0.04	0.004	0.005	14	0.06	150
	8/27	19	6.6	0.19	0.02	0.000	0.004	16	0.01	120
C-150	8/20	20	5.5	0.55	0.03	0.000	0.004	14	0.07	100
	8/25	18	6.5	0.22	0.04	0.000	0.004	16	0.05	120
	8/27	19	6.0	0.15	0.03	0.000	0.005	16	0.20	120

Table D-5 presents the various kinds of plankton organisms (in number per milliliter), as well as the wet weight and weight of organic matter (both in grams per liter).

From the figures given, there appears to be little or no build-up of plankton within the reservoir at this season of the year. The forms present were quite similar to those in other unimpounded portions of the river and occurred in the same relative proportions, with a possible slight increase in green and blue-green algae and protozoans. The increase in protozoans could probably be attributed to increased organic pollution downstream, rather than to the effects of the impoundment.

As the seasonal variation in plankton is generally large, studies at other seasons of the year would be advisable to determine if the reservoir had any effects on these organisms. An examination at extreme low water conditions, generally occurring just before the spring flood, would probably give the best indication of any possible effect of the reservoir on plankton.

Bottom Organisms

The numbers and weights of bottom animals in the quantitative collections made at the various ranges are shown in table D-6. From the limited number of samples taken, bottom conditions appeared very poor and entirely different from those found in unimpounded areas of the Columbia River. The predominating animals at all ranges were oligochaete worms and midgefly larvae. The only other organisms found were a few snails and clams and an occasional amphipod. Only one mayfly nymph and no caddisfly larvae were found in any of the samples. The contrast between this area and the unimpounded Priest Rapids - Paterson area was striking, as mayfly numphs and caddisfly larvae were among the most predominant forms found in the upstream section.

The samples, while indicating the conditions on the major portion of the pool bottom, did not take into account the most productive areas within the reservoir. Such locations, very limited in extent, lie along the immediate shoreline and at the shallow gravelly points jutting out into the pool. A few of the areas examined showed mayfly nymphs, damselfly nymphs and caddisfly larvae to be reasonably abundant. A large number of amphipods (Corophium sp) were also found. Quite a few snails and an occasional crayfish were also present. Other fairly productive locations were observed at a few shallow areas where rooted vegetation had become established. The very steep drop-off of the river banks on the Washington side and the quite sandy nature of the Oregon shore limited the extent of the more productive areas.

The physical nature of most of the pool bottom was such as to discourage the establishment of bottom animals. In general, the river bed appeared to be covered with a layer of fairly coarse to fine sand, and debris consisting principally of sawdust, bark and wood fibers. This condition appeared general throughout the lower half of the pool, except in shallow shore-line sections which were kept fairly clean by wave action. Some mud deposits were observed in shore areas. It is highly probable that the sand deposits are laid down during the annual spring run-off periods. The increased sediment load present at that time is partially deposited as the river velocity is decreased in passing through the reservoir. These deposits may have a smothering effect on bottom animals. The extensive lumber operations in this area and the use of the pool in these operations would account for the large amount of debris found in the samples.

Table D-5 - PLANKTON - COLUMBIA RIVER

SAMPLING DATA				Plankton Weight		PLANKTON COUNT - AVER. - NUMBER OF ORGANISMS																									
						Per Milliliter																	Per 200 Milliliters								
Sampling Range	Mileage Index Number	Location of Sample (Cross-section)	Date of Sample	Wet Weight per Liter Milligrams	Organic Matter per Liter Milligrams	BACILLARIOPHYCEAE - TOTAL	Asterionella sp	Cyclotella sp	Diatoma sp	Fragilaria sp	Gomphonema sp	Melosira sp	Navicula sp	Synedra sp	Stephanodiscus sp	CHLOROPHYCEAE - TOTAL	Ankistrodesmus sp	Scenedesmus sp	Pediastrum sp	Actinastrum sp	MYXOPHYCEAE - TOTAL	Oscillatoria sp	PIGMENTED FLAGELLATES - TOTAL	PROTOZOA - TOTAL	Peridinium sp	FILAMENTOUS BACTERIA and FUNGI - TOTAL	CRUSTACEA - TOTAL	Copepods	ROTIFERA - TOTAL	Amoeba sp	MISCELLANEOUS	TOTAL ORGANISMS PER MILLILITER
Columbia River above The Dalles, Ore.	C-191	Surface	8/20	13.25	3.52	2,076	5	1,550	2	81	4	47	14	11	346	127	18	84	14	4	52		9	976	864	8			12		32	2,264
		Surface	8/25	2.13	0.51	4,629		4,087		153		44	54	15	237	848	158	310	10	20	59	5	25	242	214				4	2	2	5,561
		Depth		8.69	2.23	4,539	29	3,983		158	5	10	49	5	246	734	212	212	10	49	44		20	134	130	4			6	2	4	5,337
		Surface	8/27	3.92	1.16	4,215		3,599		158	5	39	20	10	315	642	44	266	10	25	10		49	335	322				10	10	6	4,916
Columbia River above Lyle, Wn.	C-182	Surface	8/24	9.17	2.64	6,098	15	4,974		281		69	49	15	655	661	35	311	29	10	64		20	248	224				2		6	6,843
		Depth		10.97	3.09	3,386		2,573		182		39	10	5	557	252	10	74	30		10		10	482	470				10	4	48	3,658
		Surface	8/27	8.50	1.94	5,547		4,743	15	148		59	64	5	478	503	39	227	10				20	530	514				4	2	4	6,070
Columbia River below White Salmon River	C-167	Surface	8/1[illegible]	13.07	2.32	502	7	233		66		18	14	16	129	95	23	52	7	2	20		7	66	54				8	8	12	624
		Depth		6.03	1.21	2,738	18	1,483	9	307	18	99	36	63	624	316	18	226	45		63		45	96	96				16			3,162
		Surface	8/22	8.75	1.97	2,687	20	1,715	5	118	5	10	20	10	739	203	5	64	20	20	103		25	101	100						12	3,018
		Depth		12.46	2.25	3,726	39	2,652	39	118	10	39	39	10	730	454	20	256	20	20	128		20	144	44				12		12	4,328
		Surface	8/25	6.15	1.52	3,737	20	2,741		222	5	44	15	10	631	425		242	25	5	20		35	1,172	1,158				8	4	44	4,217
				11.42	2.36	4,644	20	3,441	10	286	10	89	49	10	651	630	59	296	49		79		39	176	144		4	4	12	4	36	5,392
		Surface	8/27	11.76	2.22	4,891	20	4,363	5	118		39	35	10	261	435	15	197	10	20	10		39	160	124				8	6	26	5,375
		Depth		17.40	3.46	5,295	20	4,516		128	10	69	30	39	414	523	30	256	20		10		30	272	232				4		32	5,858
Columbia River above L. White Salmon River	C-163	Surface	8/22	9.47	1.87	3,135	29	2,445		113		5	10	5	446	375	49	143	5	59	192			114	102				6		2	3,702
		Depth		15.73	2.51	3,497	54	2,450	5	99	5	25	25	15	799	391	20	168	35	15	64			112	106				18	4	2	3,991
Columbia River below Stevenson, Wn.	C-150	Surface	8/20	13.32	1.87	1,678	5	1,366		25		10	25		247	238	5	94	20	10	15		44	372	368				8	8	1	1,975
		Depth		14.63	2.33	1,953	5	1,400		49	15	39	10	30	380	208	5	89	10				64	148	144				10	4		2,225
		Surface	8/25	5.13	1.18	2,328	25	1,523		143	15	10	10		582	386	20	173	15	20	49		20	1,872	1,638		2	2	8	6	26	2,783
		Depth		9.46	1.93	2,224	5	1,489		182		25	20	15	473	301	10	138	30	10	30		5	998	966				8	6	36	2,560
		Surface	8/27	5.78	1.42	2,770	5	2,095		247		30	15	25	330	445	25	227	20	20	25		15	1,280	1,258				8	2	30	3,257
		Depth		12.29	2.16	2,253	5	1,883		118		20	15	5	182	307	5	89	15	20	39		30	56	34				14	8	28	2,629

Table D-6 - BOTTOM FAUNA - COLUMBIA RIVER

SAMPLING DATA						ORGANISMS								
Sampling Range	Mileage Index Number	Distance from North Shore	Number of Samples @ Depth Taken	Date of Sample (1952)	Size of Sample and Method of Collection		Oligochaetae (Aquatic Earthworms)	Amphipoda (Scuds)	Ephemerida (Mayfly nymphs)	Diptera: Chironomidae (Midgefly larvae)	Mollusca: Gastropoda (Snails)	Lamellibranchiae (Clams)	TOTAL	TOTAL PER SQUARE FOOT
Columbia River above Lyle, Wn.	C-182	1/4 1/2 3/4	2 @ 55' 2 @ 34' 2 @ 15'	8/24	1.5 Sq.Ft. Ekman	Number	36			7			43	29
						Weight	0.04			0.02			0.06	.04
Columbia River below White Salmon River	C-167	3/4	2 @ 30'	8/22	0.5 Sq.Ft. Ekman	Number	151		1	51	2		205	410
						Weight	0.17			0.07			0.24	.48
		1/4	2 @ 90'		"	Number	141			11	1		153	306
						Weight	0.11			0.01	0.11		0.23	.46
		1/2	2 @ 60'		"	Number	7			5			12	24
						Weight	0.01			0.01			0.02	.04
		1/2	4 @ 70'	8/25	1.0 Sq.Ft. Ekman	Number	6	1		34			41	41
						Weight				0.03			0.03	.03
		3/4	4 @ 14'		"	Number	115	4		29	1		149	149
						Weight	0.11			0.07			0.18	.18
		1/4 1/2	2 @ 80' 2 @ 54'	8/27	"	Number	47			66		1	114	114
						Weight	0.03			0.10			0.13	.13
Columbia River above Little White Salmon River	C-163	1/4	1 @ 23'	8/22	0.25 Sq.Ft.	Number	43			10	13		66	264
						Weight	0.03						0.03	.12
		1/2	1 @ 45'		"	Number	3			7	1	1	12	48
						Weight				0.01			0.01	.04
Columbia River below Stevenson, Wn.	C-150	1/4 3/4	1 @ 31' 3 @ 21'	8/25	1.0 Sq.Ft. Ekman	Number	125			54			179	179
						Weight	0.09			0.07			0.16	.16
		1/2 3/4	2 @ 64' 2 @ 30'	8/27	"	Number	98			39	14		151	151
						Weight	0.06			0.04	1.62		1.72	1.72

Juvenile fish collections were quite limited in extent, being made only one to three times at each sampling range and all taken near the Washington shore. The following species were found in the various collections:

Bass, largemouth	-	Micropterus salmoides
Carp,	-	Cyprinus carpio
Chiselmouth	-	Acrocheilus alutacus
Crappie, white	-	Pomoxis annularis
Dace, speckled	-	Apocope oscula
Sculpin, rough	-	Cottus sp
Shad, white	-	Alosa sapidissima
Shiner, Columbia River	-	Richardsonius balteatus
Squawfish, Oregon	-	Ptychocheilus oregonensis
Sturgeon, white	-	Acipenser transmontanus
Sucker, coarse-scaled	-	Catostomus macrocheilus

There are no doubt many other species of fish within the pool, but these were the only ones found during this survey. Juvenile salmon are probably abundant during certain seasons of the year but would not be expected during the period this study was made. Shiners, squawfish and chiselmouth were in much greater abundance in the collections than were any other species. They were fairly numerous at all ranges within the pool but much less abundant, or at least much more difficult to collect, than in the Priest Rapids - Paterson Section. The presence of bass and crappy young-of-the-year indicate at least some successful spawning of spiny-rayed species within the pool area. A few shad juveniles collected near Stevenson, Range C-150, indicate some spawning of this anadromous species above Bonneville Dam.

Due to rough water and lack of time very little gill netting was done. One bottom-set, with a 125 yard, 1", 2" and 3" mesh, was made at Range C-167. One hundred and twenty sturgeon, ranging from 15 to 40 inches and 1/2 to 7-1/2 pounds, were taken in this overnight set. The only other fish taken at the same time was one fairly large squawfish. Other adult fish observed or taken by fishermen within the pool during this survey were numerous squawfish, some carp, a fair number of large steelhead (Salmo gairdnerii), ranging up to 25 pounds in weight, and several chinook salmon (Oncorhynchus tshawytscha), ranging up to 35 pounds. A few other species were observed in the fish ladders at Bonneville Dam, including lampreys (Lampetra sp) and white shad. Large numbers of salmon, (mostly chinook, but a few of other species) and steelhead were passing over the fish ladders during this period.

There is some commercial fishing within Bonneville pool during seasons set by the state fisheries departments of Washington and Oregon. Most of this is for blueback (Oncorhynchus nerka) and chinook (Oncorhynchus tshawytscha) salmon and is done with drift gill nets. There is also a limited amount of commercial fishing for sturgeon. Headquarters for most of these operations are in the Drano Lake, Underwood, Hood River and The Dalles areas. Fish trucks from the Astoria canneries pick up the catches at regular intervals during the season.

Excellent sport fishing is available seasonally in a few areas within the pool. Most of it is for steelhead trout and confined mainly to locations near the mouths of tributary streams. Among the best of these areas are the mouth of the White Salmon River, Drano Lake and the Mouth of the Wind River. Extensive sport fishing was observed at the mouth of White Salmon River and in Drano Lake. Numerous steelhead trout, weighing from 5 to 25 pounds were taken by fishermen, along with an occasional large chinook salmon. Most of this fishing was by trolling and casting using artificial lures, mostly spoons of some kind. It is reported that good steelhead fishing is available in some of the tributaries; in the White Salmon River up to the power dam, approximately 2 miles above the mouth; in the Wind River to Shepherd Falls; and in the Klickitat River, within the lower 25 miles. Fishing for resident trout is also carried on.

Sport fishing for sturgeon is quite extensive within the Bonneville pool. Most of it is done from the bank, generally using prepared bait in some form of salted salmon. It is reported that quite a few are caught throughout the year. A large number of squawfish are taken by sturgeon fishermen but are considered as pests and not utilized to any extent. There is a small amount of fishing for bass and other spiny-rayed species in a few back-water areas.

The very rough water frequently existing, and caused by westerly winds through the Cascade Gorge, precludes wide use of small boats for fishing and recreation. There are only a very few periods during the year when such craft can be taken out safely. Otherwise the pool would probably be used more extensively both for fishing and boating.

Biologically, the major change occurring within the impoundment appears to be the definite change in bottom fauna. The pool areas appear much less productive in this respect than similar areas in unimpounded sections of the river. The organisms present are also of a less desirable form from a fish food standpoint. This would probably have little or no effect on populations of anadromous species of fish, since the adults are not feeding while in this area and the juveniles are present for only a short period of time. It would, however, probably tend to discourage an increase in certain resident species. The physical condition of the pool, with the very steep shores, quite sandy areas, and large amounts of woody debris on the bottom, would also tend to discourage resident fish populations. Plankton conditions do not appear to appreciably change within the impoundment.

The U. S. Fish and Wildlife Service is carrying out extensive hatching operations and a rehabilitation program for salmon in this area. This seems to be proving quite successful. The sturgeon population appears to be fairly well stabilized. It might perhaps be possible to increase fishing for spiny-rayed species in certain of the back-water areas and pools separated from the main reservoir by railroad and highway fills. Reducing the release of sawdust and wood fibers from the many sawmills in the area would improve conditions for all kinds of fish and all other aquatic organisms. The abundant squawfish creates a predator problem for young salmon, but probably no more serious in this area than in other sections of the Columbia River. No methods are known at present to discourage this species.

RADIOLOGICAL EXAMINATIONS

The source of the radioactivity found in the Bonneville Reservoir, for other than background levels, is the Hanford Works of the Atomic Energy Commission located over 150 miles above the upper end of the impoundment. Any such radioactivity detected in the Bonneville area would be due to relatively long-lived isotopes. The flow time between the Hanford Works and the upper end of the Reservoir is in the neighborhood of 60 to 70 hours. The radioactivity then is probably due principally to P^{32}, which has a half-life of 14.3 days.

Water

The results of the gross beta activity densities for water samples are presented in table D-7.

The results indicate a uniform mixing of the radioactive elements across the entire reservoir and a gradual decrease of activity from an average of 27 x 10^{-8} μc/ml. near The Dalles, to 14 x 10^{-8} μc/ml. near the center and 9 x 10^{-8} μc/ml. at the lower end of the pool. There was good agreement in the 3 sets of samples collected at each range.

These values are as expected, in the light of the flow time, natural dilution, and radiological results at Hanford and Paterson. The half-life of this activity was about 2 to 3 days during the first 6 days after sample collection. It was difficult to get a good decay curve because of the delay of over 24 hours before making the initial count.

Table D-7 - RESULTS OF RADIOACTIVITY COUNTING - WATER

Distance from North Shore	Date (1952)	Gross Beta Activity Density - 10^{-8} μc/ml		
		Range C-191	Range C-167	Range C-150
1/4 (Surface)	8/20	22	12	8
	8/25	27	15	9
	8/27	32	18	11
1/2 (Surface)	8/20	22	12	7
	8/25	29	14	10
	8/27	32	18	10
3/4 (Surface)	8/20	23	8	9
	8/25	26	13	9
	8/27	29	15	12

Aquatic Organisms

The results for gross beta activity density of plankton, algae, snails, and juvenile fish are shown in table D-8. Values for individual parts of adult fish are shown in table D-9.

Table D-8 - RESULTS OF RADIOACTIVITY COUNTING - ALGAE, PLANKTON, BOTTOM FAUNA, AND JUVENILE FISH

SAMPLING DATA				GROSS BETA ACTIVITY DENSITY IN 10^{-7} μc/gm.												
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample (1952)	Algae	Plankton	Snails Gastropoda - entire	Crayfish *Astacus trowbridgii*	Bass, Largemouth *Micropterus dolomieu*	Carp *Cyprinus carpio*	Chiselmouth *Acrocheilus alutacus*	Crappie, White *Pomoxis annularis*	Dace, speckled *Apocope oscula*	Sculpin, Rough *Cottus sp*	Shiner, Columbia River *Richardsonius balteatus*	Squawfish *Ptychocheilus oregonensis*	Sucker, Coarse scaled *Catostomus macrocheilus*
Columbia River above The Dalles, Oregon	C-191	Cross-section	8/20		2,400 1,900											
		North - shore	8/25	74 62	2,600* 3,100*					1,200 1,200				2,900 3,000 2,500	1,400 1,800 3,300	5,200 4,500 4,000
		Cross - section	8/27		5,200 5,100											
Columbia River above Lyle, Wn.	C-182	North shore	8/24	48 40	4,800* 4,100*					670				1,200 660 1,500	850 1,700 1,100	
Columbia River below White Salmon River	C-167	North shore	8/19		11,000* 13,000*											
			8/21	520 550			1,000			1,100				2,200 2,500 3,400	1,300 650 2,500	
		Cross - section	8/22		4,000 3,900											
			8/25		5,200 4,700											
			8/27		4,400 4,400											
Columbia River above Little White Salmon River	C-163	Cross - section	8/22		6,600 4,900											
		North shore	8/26	410 430		270 280		4,900 4,200	2,100 1,200			4,400 5,300	1,600 2,700	580 2,800 4,000	3,600 4,000 2,800	3,800 2,300 2,400
Columbia River at Collins, Wn.	C-158	North shore	8/21	260 300		280 460 940				1,200 1,100 1,400				970 800 890		
Columbia River below Stevenson, Wn.	C-150	Cross - section	8/19	270 180						1,200 1,300	2,600 3,000		2,700			
			8/20		13,000 13,000											
		North shore	8/25	130	5,000* 4,600*					1,000				830 1,400 2,100	930 1,500 1,300	1,700
		Cross - section	8/27		5,300 4,300											

(*) Represents Cross-sectional sample.

Table D-9 - RESULTS OF RADIOACTIVITY COUNTING - FISH, ADULT (INDIVIDUAL PARTS)

SAMPLING DATA								GROSS BETA ACTIVITY DENSITY IN 10^{-7} μc/gm.								
Sampling Range	Mileage Index Number	Location of Sample	Date of Sample (1952)	Kind of Fish	Length of Fish (Millimeters)	Weight of Fish (grams)	Sex and Condition (*)	Scales	Muscle	Liver	Bone	Ovary	Testes	Kidney	Stomach and Intestinal Contents	Skin
Columbia River	C-167	North Shore	8/23	Squawfish Ptychocheilus oregonensis	370	545	F-Ud.	79	51	150	100	75		81	350	6
				" "	270	265	M-Ud.	85	49	200	75			90	1,000	3
			8/28	" "	430	800	F-Ud.	85	34	510	96	49		170		15
			8/28	Sturgeon Acipenser transmontanus	1,000	3,400	F-Ud.	16	2	150	3	56		42	1,800	28
				" "	690	1,800	F-Ud.	180	24	140	100			210	580	140
				" "	560	1,200	F-Ud.	91	60	260	64	80		280	2,200	160
				" "	480	560	M-Ud.	550	89	910	99		340	790	1,600	300
				" "	410	370	F-Ud.	1,700	74	630	110	410		720	1,500	380
				" "	380	280	F-Ud.	1,100	95	570	160	190		600	1,800	360
				" "	380	260	M-Ud.	1,100	130	660	220		130	660	2,200	640

(*) F = Female; M = Male; Ud. = Undeveloped.

Measurable amounts of radioactivity were found in all the types of aquatic organisms examined throughout the pool. There was no significant difference in these values at the various ranges. The variation in individual samples at the same range was equal to or greater than that between ranges.

Results for plankton and algae were considerably less than those found in the Columbia River at Paterson (approximately 90 miles upstream from the head of the reservoir) but values for juvenile fish and some other aquatic animals were in the same order of magnitude as those found upstream.

The pattern for radioactivity densities found in the Bonneville Area was somewhat similar to that established in the Priest Rapids - Paterson Section of the Columbia River. The magnitude of the differences between types of organisms, however, was much less. In the upstream section activity values for plankton and algae, which took nutrients directly from the water, were highest. Next in order were bottom animals and then fish. The latter accumulate activity principally through feeding.

Values for plankton, which were ten times higher than for juvenile fish in upstream sections, were only slightly higher for plankton (1.9 to 13 x 10^{-4} $\mu c/gm$) than for fish (0.58 to 5.2 x 10^{-4} $\mu c/gm$) in the reservoir.

The probable reason for the relatively small difference is that most of the short-lived activity has disappeared by the time the water reaches this area and the activity present in both plankton and fish is due to longer-lived isotopes such as P^{32}. Upstream, on the other hand, a large part of the activity in plankton is due to short-lived isotopes adsorbed directly from the water. Very low values (0.04 to 0.55 x 10^{-4} $\mu c/gm$) obtained for algae from the Bonneville pool were probably due to the samples being taken in shore areas away from the main channel. Water activity values were also lowest in the shore areas.

All species of juvenile fish appeared to concentrate radioactivity in somewhat similar amounts. Highest values were found in suckers and dace but individuals of other species were found to contain nearly equal amounts. Only two species of adult fish were examined. Values for sturgeon were generally higher than those for squawfish. Stomach contents contained the most activity, ranging up to 2.2 x 10^{-4} $\mu c/gm$, with muscle giving the lowest result, a maximum of 0.13 x 10^{-4} $\mu c/gm$.

From studies of radioactivity in the Priest Rapids - Paterson Section, it is expected that radioactivity in aquatic organisms in the Bonneville area during the period of this study were not quite at maximum levels. Values possibly twice as great may be expected a month or two later. Radioactivity levels found in aquatic organisms in Bonneville Reservoir, while significantly above natural background, would be expected to have little or no effect on aquatic organisms or the use of these organisms.

Bottom Muds

The radioactivity results for the limited number of bottom mud samples are given in table D-10.

The half-life of the samples, as determined from gross beta decay studies was about 40 days, indicating that the activity may be due to an isotope similar to Fe^{59}, which has a half-life of 46.5 days. The alpha activity levels

were low, but definitely above minimum detectable limits.

Table D-10 - RESULTS OF RADIOACTIVITY COUNTING - BOTTOM MUDS

Sampling Range	Distance from North Shore	Date (1952)	Activity Density - 10^{-7} μc/gm	
			Gross Beta	Alpha
C-191	3/4	8/25	160	-
		8/27	210	4.7
C-167	1/2	8/20	65	3.3
	3/4	8/20	45	1.8
		8/25	77	2.3
		8/27	130	5.3
C-150	1/2	8/20	13	2.3
		8/25	87	5.9
		8/27	78	4.7